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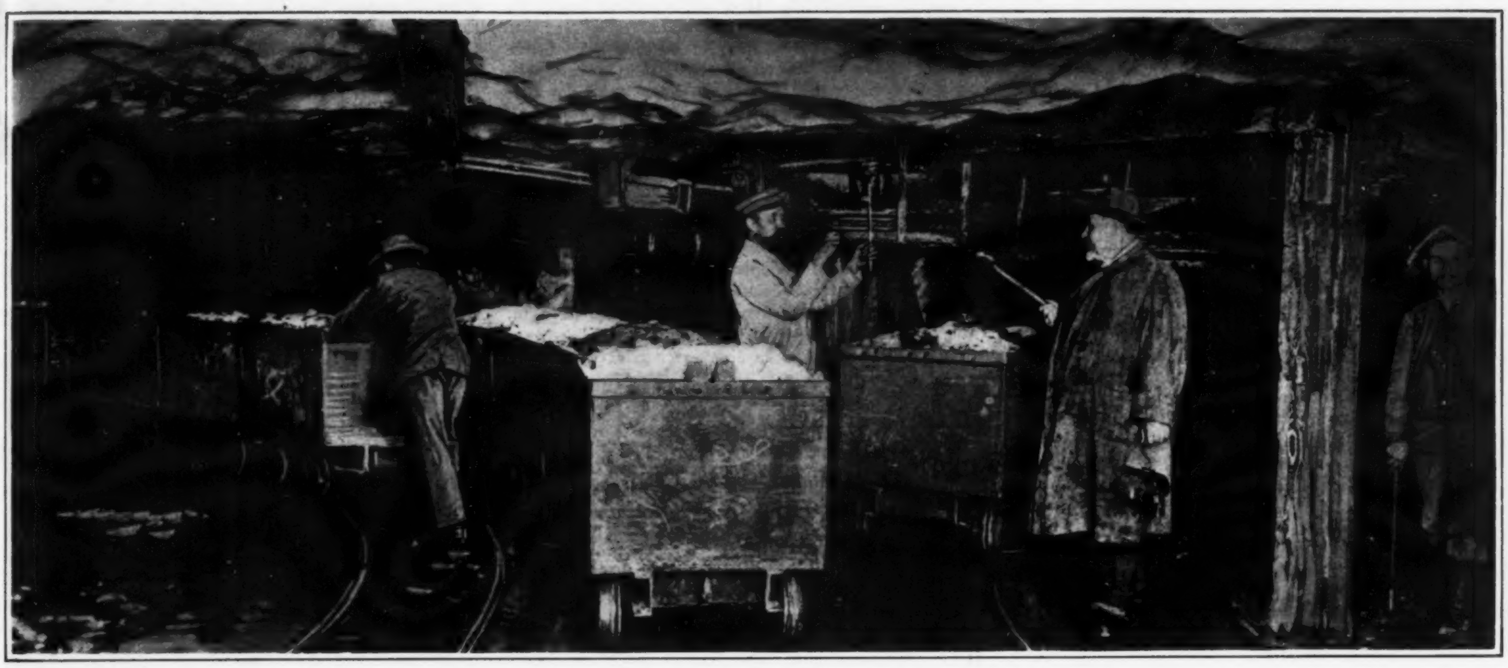


Ropeway hauling trucks in German potash mine.

Working kainite in a German potash mine.

THE GERMAN POTASSIUM SALTS.—[See page 372.]

On the Structure of the Universe—I*

The Ultimate Object of Stellar Astronomy

By H. Spencer Jones, M.A., B.Sc., Chief Assistant, Royal Observatory, Greenwich

It may be said with a good deal of truth that the ultimate object of stellar astronomy is to discover the solution to the problem of the structure and the evolution of the universe. The many recent researches upon the distances and distribution of stars, upon the relative distances of stars of different types, upon the numbers of stars of different magnitudes, and upon allied topics, have all contributed in throwing some light on this problem, which, because of its complexity and baffling nature, because also it is the most far-reaching with which the mind has to deal, has fascinated and engaged the attention of men almost from the dawn of civilization. The Greek philosophers supposed the world on which they lived to be the center of the universe, and that the sun, the planets, and the stars all rotated around it, and they devised ingenious theories to account for the observed motions of the planets. Our knowledge has advanced a great distance since their time, yet, although many facts have been accumulated, we have so far taken only the first few steps toward a solution. This is not surprising when it is remembered that for much of our knowledge we are dependent upon photography, the application of which to astronomy is still of quite a recent date. Except for the nearest stars, the refined measurements necessary for determining stellar distances have only been made possible by the development of photographic methods. The problem of the present structure of the universe is, indeed, as Kapteyn has pointed out, the problem of the distances. If the distance of each star were known in addition to its position in the sky, its position in space would be determined, and our knowledge of the present structure would be complete. To fix the changes in the structure, it would then only be rifts, but on the whole lying very nearly in a plane which is inclined at a few degrees to the ecliptic, and which intersects the celestial equator in the constellations of Aquila and Monoceros. It is important as being the plane of symmetry of the stellar universe, and the coördinates which express the position of a star relative to it are called its galactic longitude and latitude, the longitude being measured eastward from the point of its intersection with the celestial equator in Aquila.

It might not unnaturally be expected that the bright stars are, on the average, comparatively near to us. We should, therefore, expect them to be distributed more or less uniformly in neighboring space, and to exhibit no decided concentration toward the galaxy; for, if the near stars showed such a concentration, it would indicate a conical structure of the universe, with our solar system at the apex of the cone, and it is very improbable that our solar system occupies such an exceptional position. Table I exhibits the distribution of stars down to various magnitude limits in nine zones galactic latitude, each 20 degrees wide:

The second column gives the density per square degree of stars down to the visual limit of 6.0 meters as calculated by Houzeau. The third column gives the number of stars in the *Bonner Durchmustering* of Argelander and Schönfeld, down to a limit of 9.0 meters, as corrected by Seeliger to allow for the fact that the brightnesses were overestimated in regions containing only a few stars, and underestimated in the denser regions. The fourth column contains the densities derived from the Herschel star gages—counts of stars visible in a definite area in the field of Herschel's 18-inch reflector. These include all stars down to a limit of about 14.0 meters. From the above table it will be seen that the naked eye stars exhibit a slight but perfectly definite preference for the galaxy, indicating that a proportion of the stars which are visible in the Milky Way are either really situated in, and form part of it, or are in some way definitely connected with it. That this is so, is supported by the fact that some of the brightest stars have parallaxes too small to measure. From an examination of the near stars—which, on the average, are those of large proper motion—Kapteyn concludes, as might be expected, that these are distributed uniformly, and have no connection with the Milky Way. Referring again to the table, it is seen that the stars down to the ninth magnitude are nearly three times as dense in the Milky Way as at the galactic poles, while those in Herschel's star gages are nearly twenty times as dense, this large ratio being due to the fact that the star clouds in the Milky Way contain an immense number of very faint stars. This latter result is apparently contradicted by some recent star-counts made by Messrs. Chapman and Melotte at the Royal Observatory, Greenwich, based upon a series of photographs of the whole sky taken by the late John Franklin-Adams. This investigation indicated that the galactic concentration did not vary greatly over the range 5.0 meters–17.0 meters of photographic magnitudes. An explanation of this discrepancy has been suggested by Prof. H. H. Turner—viz., that the galactic regions may contain a very large number of faint red stars visible in Herschel's telescope, but too red to affect the photographic plate. A similar effect would be caused if, as is more than probable, there is absorbing matter in space, which scatters the light of short wave-length, and makes the distant stars appear reddish, similar to lights seen through a fog, and so incapable of affecting the photographic plate. In any case, however, it is certain that there is a very marked flattening of the system as a whole toward the Milky Way.

A comparison of any of the above north galactic zones with the corresponding south zones shows that in each case the density in the southern zone is greater than that in the northern; the explanation of this fact (which is generally accepted) is that our solar system lies somewhat to the north of the galactic plane, and a close study of the course of the Milky Way in the heavens lends support to this view. Struve found that it does not trace out a great circle on the celestial sphere whose center is our solar system, but a small circle at a distance of about 88 degrees from the south galactic pole.

Of still greater interest is an examination of the galactic concentration of stars of different types. It is believed that the stage in its evolution at which a star has arrived can be told with considerable certainty from its spectrum. The classes in the supposed order of evolution are denoted by the letters *B*, *A*, *F*, *G*, *K*, *M*, *N*. The spectra of stars of class *B* are characterized by strong helium lines, and those of class *A* by strong hydrogen lines, other lines being comparatively weak. In classes *F*, *G*, *K* the hydrogen lines become progressively weaker and the metallic lines more and more prominent. Stars of class *G* have spectra similar to our sun, which is itself a *G* star, and which contain numerous fine metallic lines. In classes *M*, *N* flutings due to carbon compounds make their appearance. The stars of early type are supposed to be the hottest and gradually to cool as they get older.

The spectral types of an immense number of stars have been determined at Harvard, and Prof. Pickering has tabulated the numbers of different types, brighter than the visual limit 6.5 meters, in eight zones of galactic latitude, chosen so as all to have practically an equal area. His results are given in Table II., in which in each column after the first are given the number of stars of the type at the head of the column, for the eight zones whose average galactic latitude is given in the first column.

If the stars of each type were distributed uniformly over the sky, the numbers in each vertical column should be approximately equal. It will be seen that in no case is this so, and that while the stars of type *B* exhibit a very strongly marked crowding toward the galaxy, the distribution in the various zones becomes more uniform with successive spectral types, until with class *M* there is little or no indication that the density in the galaxy is greater than that at the galactic poles. The most remarkable concentration is, however, shown by a small class of stars known as Wolf-Rayet stars, whose spectra apparently indicate a transition stage between nebulæ and *B*-type stars, and which therefore are to be regarded as preceding the *B* stars in the order of evolution. Of the ninety-one known Wolf-Rayet stars, seventy are in the Milky Way and all the remainder are in the Magellanic Clouds. A similar concentration is shown by the gaseous nebulæ: Hertzsprung found for the pole of their plane of concentration the position R. A. 192.7 degrees, December + 28.1 degrees, in close agreement with the position of the galactic pole derived by Pickering—R. A. 190.0 degrees, December + 28.0 degrees.

These facts must be considered in conjunction with a remarkable result first announced by Prof. W. W. Campbell, from an analysis of the line-of-sight velocities of stars measured at the Lick Observatory—viz., that the average velocity of the stars of given spectral type increases with progression of the type. This is illustrated by Table, III summarizing Campbell's results:

The same result has been found from a discussion of the proper motions by Boss and by the present author. The interpretation of this phenomenon is by no means easy. Although all stars are not of equal age, some having condensed from nebulous matter at a much later date than others, yet it is natural to suppose that gravitational

Table I

Galactic Latitude Zones.	Densities of stars down to various limits of magnitude.		
	6·0 m.	9·0 m.	14·0 m.
+ 90° to + 70°	0·113	2·78	107
+ 70 „ + 50	0·122	3·03	154
+ 50 „ + 30	0·124	3·54	281
+ 30 „ + 10	0·145	5·32	560
+ 10 „ − 10	0·160	8·17	2,019
− 10 „ − 30	0·154	6·07	672
− 30 „ − 50	0·129	3·71	261
− 50 „ − 70	0.124	3·21	154
− 70 „ − 90	0·125	3·14	111

Table III

Spectral class.	Number of stars.	Average radial velocities in km. per sec.
O and B	141	8·99
A	133	9·94
F	159	13·90
G and K	529	15·15
M	72	16·55

necessary to know the motion of each star. For the brighter stars we have fairly accurate observations of their positions which date back 160 years, and from comparisons with modern observations their proper motions —i. e., their apparent motions in the sky—can be determined with great accuracy. For the majority of the fainter stars we have not, however, sufficiently distant observations for determining accurately their proper motions. The measurement of the velocities of stars in the line of sight is also one of the most recent developments of astronomy, so that our knowledge of these is still in its early stages. As we cannot hope for some time to obtain sufficient information thus to solve the problem directly, it becomes necessary to get such indirect information as we can, and bound up with the problem of the present structure is the additional and more difficult problem of the evolution of the universe—more difficult because to mark its changes we must measure not by hundreds but by millions of years.

The questions which even a very cursory examination of the problem raises are very numerous. Is our universe finite or infinite in extent? Can we, with the aid of our telescopes, penetrate to its extremities, and number the stars? If it is finite, are there other stellar universes existing outside our own, and if so, in what relation does ours stand to them? How has our universe been evolved, what will be its end, and how long its duration? What is its form and where is its center? To some of these questions we can give answers with more or less certainty, but to others of them we cannot yet reply.

In all these investigations, the Milky Way holds a position of fundamental importance. Some part of the Milky Way may be seen on any clear night in the year, but it is seen best in early winter, when it passes near our zenith in the evening. It is a broad, luminous stream of faint stars, with many branches and dark

* From *Science Progress*.

forces have acted upon the matter composing every star for the same length of time. On the other hand, the fact that the average velocity of a star increases with its age, and that the velocities of the early-type stars are very small, seems to suggest that these gravitational forces due to the stellar system as a whole do not become effective until the nebulous matter has condensed into a star. It may possibly be that the resultant velocity of the materials which go to form the star is practically zero. However, the facts which we have gathered together would seem to indicate that the birth of stars occurs mainly in the galactic plane. The stars then acquire velocities under the general attraction of the whole stellar system—the law of attraction being doubtless somewhere between an attraction varying directly as the distance (the law of attraction due to a uniform distribution of matter) and an attraction varying inversely as the square of the distance (the law of attraction when the attracting mass is concentrated at one point—as in the motion of the earth around the sun). The stars of early types *O* and *B*, owing to the comparatively small time which has elapsed since their birth, have small velocities and are strongly condensed in the galactic plane. The stars of later types having been born earlier have had time to acquire larger velocities and to stray further from the galactic plane, so that we find the type *M* stars very uniformly distributed. If this be the true explanation, it is not free from difficulties. If the stars, are, as we have supposed, born in the galactic plane, the attraction under which they move will be in the same plane, so that it is not easy to see how they can move out of it. To avoid this difficulty, Prof. Eddington has conjectured that the stars of types *K* and *M* may have been formed originally in a more spherical and uniform distribution than the stars of early type, and that possibly, for some reason which we do not know, the birth of stars was retarded in the galactic plane. It is a well-known fact that the stars of early type do on the whole move parallel to the galactic plane, as we should expect, and this fact has been used by Prof. Kapteyn to predict their parallaxes with a considerable degree of accuracy.

Another alternative explanation which Prof. Eddington has suggested is that in the galactic regions, richly supplied with star-forming material, the tendency has been to form large stars which have developed very slowly, while away from the galaxy small stars have been formed, which have run through their course of development quickly. This would account for the predominance of early-type stars in the galactic plane; but it raises other difficulties, and does not appear to explain the increase of average velocity with the progression in type. One feels that one is treading on uncertain ground, and that these hypotheses are merely speculative, with little solid foundation. The facts, nevertheless, must be of fundamental importance in any theory of the structure of the stellar universe.

A few further facts must be considered before we can form a general idea of the structure of our sidereal system. So far nothing has been said as to the average distances of stars of various types. Many investigations have been made to determine this, and they all agree in their main results. Briefly stated, these are that the most distant stars are those of very early type, and that the average distance gradually decreases with advancing type, until the solar type is reached. The stars of this type are on the average the nearest to us. Those of still later types are more distant, and the red or *M* stars are the most distant of all, after the *B* stars. The great average distance of the helium or early-type stars is accounted for by the fact that they are mostly in the distant galactic star clouds. We may thus picture our sidereal system as consisting of a central region containing stars of various types, but chiefly the later ones, more or less uniformly distributed about their center; outside this central region lies the belt of the Milky Way at such an immense distance from our solar system that it has not yet been measured with any certainty, constituted mainly of early-type stars, and containing many nebulæ and nebulous clouds. An influence of the galactic belt on the inner region is found in the tendency of its stars to concentrate toward the galactic plane, more particularly in the case of the earlier types—although we are not yet able to assign definitely the cause of this, nor the way in which the system has arrived at its present form.

TABLE II

Latitude.	B.	A.	F.	G.	K.	M.	Total.
+ 62·3°	8	189	79	61	176	56	569
+ 41·3	28	184	58	69	174	49	562
+ 21·0	69	263	83	70	212	57	754
+ 9·2	206	323	96	99	266	77	1,067
− 7·0	161	382	116	84	239	45	1,027
− 22·2	158	276	117	100	247	69	967
− 38·2	57	161	94	59	203	59	633
− 62·3	29	107	77	67	202	45	527

The further question arises as to whether our sidereal universe is finite or infinite in extent. It is a well-known fact that when the number of stars of magnitude $m + 1$ is compared with the number of magnitude m, the former is found to be between three and four times the greater. Now by the definition of the magnitude of a star, a star of magnitude m gives 2.512 times as much light as a star of magnitude $m + 1$ (log. 2.512 = 0.4, so that a ratio of 100 : 1 in apparent brightness corresponds to a difference of 5 magnitudes). It follows from these facts that all the stars of magnitude $m + 1$ give together more light than all the stars of magnitude m. This result can only hold for moderate values of m, because otherwise the heavens would shine with a blaze of light greater than the noonday sun, due to the innumerable faint stars. It follows that at some stage the number of stars of a given magnitude must reach a maximum and afterward begin to decrease, and this leads one to expect that the total number of the stars may be finite in amount. That this is so, is indicated by the counts of stars of different magnitudes recently made by Messrs. Chapman and Melotte. The results of this count are shown in Table, IV in which the second column gives the *total* number of stars down to the limit of magnitude (photographic) in the first column.

It will be seen from this table that after the 15th magnitude, the ratio of the number of stars of any given magnitude to the number of the next brighter magnitude is less than two. By extrapolation from these results Chapman and Melotte estimate that the number of stars down to a magnitude of about 22.0 is half the total number of stars, which, they conclude, "is not less than one hundred thousand millions, and cannot much exceed twice this amount." This result is dependent upon the assumption that there is no scattering nor absorption of light in space; but although there is considerable evidence that such an absorption does occur, the most reliable estimates of its magnitude indicate that its amount is so slight that it cannot very greatly modify the general conclusion. It follows that we must regard our stellar universe as finite in extent—although its dimensions are so vast as to stagger the mind—and contemplate the possibility of the existence of other, and independent universes, outside it.

TABLE IV

Magnitude.	Number of stars.	Magnitude.	Number of stars.
2	38	11	698,000
3	111	12	1,659,000
4	300	13	7,646,000
5	950	15	15,470,000
6	3,150	16	29,510,000
7	9,810	17	54,900,000
8	32,360	18	(91,200,000)[1]
9	97,400	19	(144,000,000)[1]
10	271,800		

[1] These are extrapolations.

It has been shown above that our universe consists of a central mass more or less globular in shape, and that outside this lies the Milky Way, stretching out to immense distances and containing a large proportion of faint stars. This has suggested that the system may really be a spiral nebula, and that the other spiral nebulæ may be separate universes. Astronomers divide nebulæ into three classes. These are:

(1) The irregular nebulæ of which the Great Nebula in Orion is the most conspicuous example. This class comprises nebulæ of many varied shapes, whose names are often given from a more or less striking resemblance to some terrestrial object, such as the Dumbbell Nebula, the Crab Nebula, the North America Nebula, the Keyhole Nebula, and many others. To the same category belong the nebulous backgrounds, obviously associated with stars, such as the nebulosity around the Pleiades, and in the constellation of Taurus. These irregular nebulæ occur mainly in the neighborhood of the galaxy, and undoubtedly belong to our system. In many cases, they show undeniable connection with certain stars.

(2) The second class is known as the Planetary or Gaseous nebulæ. They were first classified as such by Sir William Herschel, but he did not originally recognize their nebulous nature. "We can hardly suppose them to be nebulæ," he says; "their light is so uniform as well as so vivid, their diameters so small and well defined as to make it almost improbable that they should belong to that species of bodies." He considered that they might be planets attached to distant suns, but recognized that this supposition was untenable. Their spectra present many analogies to the spectra of the Wolf-Rayet or gaseous stars, and, like the latter, they occur almost exclusively in the Milky Way. This apparent connection seemed to indicate that nebulæ passed, in the ordinary course of evolution, into the gaseous or early-type stars. This hypothesis received a rude shock when measurements of the line-of-sight velocities of these objects became possible. If by evolution they passed into early-type stars, their average radial velocity should be very small, of the order of 5 or 6 kilometers per second. The first few results obtained indicated that this was far from being the case, and enough measurements have now been made to assert definitely that, so far from their velocities being small, their average velocity is considerably greater than that of the late *M*-type stars—the average line-of-sight velocity of the latter being about 17 kilometers per second, and that of the planetary nebulæ of the order of 40 kilometers per second. Several of them have been found to possess extremely high velocities, even as great as 200 kilometers per second. How the planetary nebulæ are to be fitted into the general scheme of stellar evolution remains at present one of the unsolved problems of astronomy. The suggestion has been made that they have been formed from stars through collisions with other stars. One would naturally expect such collisions to occur most frequently in the Milky Way, where the stars are densest, but their huge velocities are not thus accounted for.

(3) The third class of nebulæ, and the class which is by far the most numerous, is that of the Spiral nebulæ. Their discovery was the one striking achievement of the great Parsonstown reflector, constructed by Lord Rosse. Fath has estimated that there are at least 160,000 nebulæ of all kinds, so that the number of spirals must be very great. By far, the most conspicuous object of this class is the great nebula in Andromeda, easily visible to the naked eye as a small blurred patch, very different from a star in appearance. It was the only nebula discovered before the invention of the telescope. Photographs show it to consist of a bright central nucleus, with long, spiral, nebulous arms wreathing around it. The spiral nebulæ that we know are placed at all inclinations to our solar system. The Andromeda nebula is seen obliquely. Many, like the Whirlpool Nebula, are seen perpendicular to the plane of the spiral arms; in this case, and in others, the two arms are clearly seen starting out from opposite edges of the central nucleus. Some, again, are viewed edge on, and in these the spiral arms are seen as a narrow line, evidence that they lie in one plane. This line is seen dark where it crosses in front of the central nucleus, owing to the scattering which the light from the latter undergoes in passing through the arms. This is the kind of nebula to which our sidereal system has been compared. From a careful consideration of the structure of the Milky Way, obtained by combining all the available photographs, C. Easton has recently given a hypothetical representation of it in the form of a spiral, in which account has been taken of all its prominent features. This attempt to account for the structure of the Milky Way on the spiral hypothesis is very interesting and instructive.

(To be continued.)

Women As Munitions Makers

OWING to the scarcity of male labor in England the experiment was made of employing women for operating the lighter machine tools in the shops making war material, particularly shells, and the result has been satisfactory. The women have been quick to learn, and the work they are turning out is said to be accurate and fully up to previous standards. Moreover, in many cases, the output has been increased, while there are many instances where the women have suggested valuable improvements, both in machines and processes.

In connection with the increased output, mention may be made of a condition imposed by the unwritten laws of the labor unions. In a certain foundry it was understood that four molds per day was the regular work of a molder on one class of work, but the union permitted an increase of one mold a day. The proprietor took an unskilled agricultural laborer into his private laboratory foundry, and, after a short period of instruction, without informing him what the regular men were doing, he soon was turning out fifteen perfect molds a day without undue exertion.

At the foot of a shaft in a potash mine.

Mining potash with an electrically driven drill.

The German Potassium Salts

A Fertilizing Material Indispensable to the Agriculturists of the World

By Dr. Alfred Gradenwitz

The remarkable standing of German agriculture is due to the assistance of a highly developed science rather than to the excellence of the soil or the advantages of a privileged climate. In fact, Nature, in Germany, has, in both respects, been rather sparing of her bounties. However, the country possesses one treasure of inestimable value, viz., its deposits of potassium salts, which are not found in any appreciable amounts outside Germany, and on which the agriculture of the world is, to some degree, dependent.

The present state of temporary national isolation, following on a period of practically unlimited exchange, lends additional interest to the potassium salt problem, some aspects of which are discussed in the following:

The potash in plants serves to produce and convert carbo-hydrates—starch, sugar and cellulose—from the carbonic acid of the air (absorbed by the leaves) and from the water supplied by the roots. In the absence of potash, starch and sugar are only formed insufficiently, and the yield of cereals, potatoes, etc., remains far below the average.

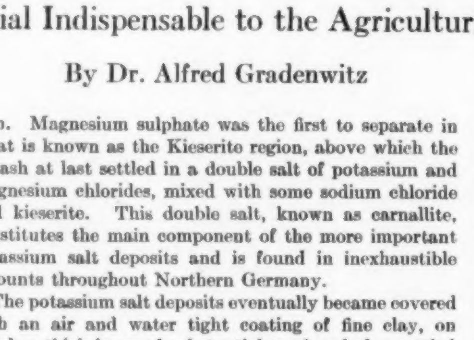
A skilled eye recognizes at a glance whether a plant does not receive its proper potash supply. There is, at first, a luxurious development of the leaves, so that superficial observers are inclined to deny the importance of potassium fertilizers. This, however, is at a later stage followed up by an absolute standstill in the development of the leaves and by premature withering. In the case of great deficiency in potash, the leaves and, soon afterward, the remainder of the plant, will die prematurely. In a test made at the Bernburg Experimental Station, the sugar contents of a beet-root would decrease from 16 to 8 per cent. On the other hand, an adequate supply of potassium salts not only furthers the production of those materials for the sake of which most agricultural plants are cultivated, but increases the resistance of plants against animal and vegetable pests, as well as against freezing.

The amount of potash required by different kinds of plants varies enormously. Some—e. g., barley and wheat—are contented with very small quantities, while others—e. g., rye, oats, potatoes, beets, many leguminous plants and tobacco—are very exacting in this respect. Again, there are many kinds which, though satisfied with small amounts, require their potash in a soluble form, etc.

All soils containing less than 0.2 per cent of potash will benefit from fertilization with potassium salts. This applies, apart from sand, to all marshy soils. Sandy loam also, in most cases, requires a potash supply, in opposition to an opinion largely prevalent among agriculturists. Special fertilizing tests should be referred to in order to ascertain whether or not a given culture requires an addition of potash to its soil. Such tests, however, are readily made even by the smallest farmer.

The German potassium salt deposits were formed by gradual settling in a branch of the ocean which, once upon a time, covered a large portion of Northern Germany. When the saturation of the brine had reached a certain degree, the least soluble salts, viz., carbonate and sulphate of lime, would be the first to separate, while the sodium, potassium and magnesium salts still remained in solution, there being a continued, though not regular, water supply from the ocean. As, however, evaporation advanced, the main part of the rock salt separated in its turn, thus becoming the mighty base of all present potash beds. The mother-lye now contained, besides sodium compounds, only magnesium and potassium salts, which concentrated the more rapidly as the high temperatures and violent storms activated evaporation. Magnesium sulphate was the first to separate in what is known as the Kieserite region, above which the potash at last settled in a double salt of potassium and magnesium chlorides, mixed with some sodium chloride and kieserite. This double salt, known as carnallite, constitutes the main component of the more important potassium salt deposits and is found in inexhaustible amounts throughout Northern Germany.

The potassium salt deposits eventually became covered with an air and water tight coating of fine clay, on which a thick layer of substantial sand and clay settled in course of time. Great variety was, however, produced in the composition and arrangement of the salt beds by the water entering through any fissures. Apart from carnallite, there are some other potassium minerals of importance to the agriculturist, viz., hard salt, produced from carnallite by the action of water, washing away the magnesium chloride; sylvinite, another product of carnallite, freed also of its kieserite and kainite, in connection with which only magnesium chloride has been washed out.



Surface works at a German potash mine.

The carnallite, kainite, hard salt, and sylvinite are blasted out of the deposits, 1,000 to 3,000 feet in depth, by means of explosives, after which they are taken to the surface in cages and ground to fine powders immediately suitable for use as fertilizers. From carnallite there are, however, also made by artificial processes—dissolving, crystallizing and drying—special fertilizers containing a high percentage of potash, of which a 40 per cent potassium salt is of growing importance for German agriculture.

The German potassium industry was, of course, deeply affected by the outbreak of the present war. Exports to the United States, which of late years amounted to about $14,000,000, decreased immediately very considerably, because the German shipping companies had to discontinue their service, while neutral lines could not offer sufficient cargo space for the quantities of potassium salts which had been ordered. Moreover, the German government issued a temporary export prohibition, which was not removed until the end of September. In fact, only 60,000 tons could be exported to the United States in the months from August to December, inclusive, while 578,000 tons had been shipped in the corresponding period of the previous year. This resulted in a serious shortage of potassium salts, and the prices of potassium chloride rose from $38 to $42 to $80, and even $120 per ton. Such prices, however, could only be paid by chemical works, and not by agricultural concerns. At the end of January last, the export prohibition was renewed, thus bringing shipments to a standstill, so that fancy prices of up to $200 per ton were demanded. This state of affairs is the more inconvenient as potassium salts cannot be dispensed with for the cultivation of the most important crops of North America, such as cotton, tobacco, sugarcane, corn, fruit, and many other vegetables.

There are at present 193 potassium salt works in operation in Germany, while another 100 are being erected. These represent an invested capital of upward of $400,000,000, and are combined in what is known as the Potassium Syndicate (Kalisyndikat), Ltd., with headquarters in Berlin. In mining and in factories the German potassium industry employs about 2,600 persons in various positions, as well as 45,000 workmen. About 2,200 boilers produce the more than 350,000 horsepower required for a total of 2,700 engines. The average daily production, in normal times, amounts to 3,870 carloads, each of ten tons, and rises at times of brisk business, in spring and autumn, to 6,000 carloads.

The Potassium Syndicate embraces the whole world in its business operations. It has everywhere abroad its own representatives, and in all important countries its own experts, whose task consists of instructing farmers in the proper way of using the salts. The potassium industry also embraces the world literally, in so far as the sacks required for last year's shipments, if placed in a row, would reach more than twice round the equator.

The following table shows the amount of potassium salts used per square kilometer of tillable land in Germany and the United States, respectively, and strikingly illustrates the rapid advance in the course of the last few years:

Year.	German Empire.	United States.
1890	68 lbs.	12 lbs.
1900	298 "	30 "
1913	1,364 "	107 "

With the increased use of potassium in Germany, there was, of course, connected a corresponding increase in the average annual yields.

Mica from India

According to the *Engineer*, the Hazaribagh district in India is one of the most valuable mica-producing areas in the world. Except for a very small amount from Sweden, all the "ruby" mica comes from Chota Nagpur, and India yields more than half the world's output of mica generally. The country where it is found is of a jungly nature, and this renders observation of the prospecting coolies a difficult matter. These coolies scoop away the earth and find the mica generally at a comparatively small depth from the surface. It is then in irregular lumps, usually not more than 12 inches to 15 inches long, and 6 inches or 8 inches thick. This is split into scales or laminae. Large sheets are the most valuable, and a piece 30 inches square would probably fetch 100 rupees. When split into sheets it is classified according to size and packed in what are known as books. It is then ready for export. According to the *Pioneer Mail*, however, it is very seldom that a large sheet finds its way to the owners of the land on which it is discovered. The coolie usually hides it in the ground, and subsequently sells it to an agent. The nearest parallel to what occurs is found in illicit diamond buying in Kimberley and other parts of South Africa. Although the expenses incurred in working mica are extraordinarily small, the business does not pay if no large "books" are obtained. Consequently, if a firm is consistently being robbed of its best finds, it naturally falls, and this is the reason for the failure of so many firms.

A 5,000-Volt, Direct Current Electric Railway

Operating Trolley Cars With the Highest Voltage Yet Attempted

By Irving B. Smith

ONE of the important electrical events of the year was the recent announcement by the Michigan United Traction Company that it has been running cars regularly from a 5,000-volt direct current circuit. This is the highest direct current voltage ever used for operating motors and marks a decided step in advance in electric railway practice.

To one accustomed to the transmission of electric energy at 60,000 and 100,000 volts, 5,000 volts does not seem particularly remarkable, but remember, this is *direct* current, not *alternating* current.

The voltage of alternating current can be readily raised or lowered by means of transformers, which consist merely of coils of wire and have no moving parts. Hence, alternating current can be generated at any convenient voltage, stepped up to a voltage high enough to be transmitted economically, and then reduced to a safe value for use.

But direct current does not possess this flexibility. No such simple means are available for altering its voltage, so that if high voltage is wanted for transmission, the current must be generated and utilized at that voltage. The difficulties in handling such currents, especially in machines that have a commutator (an essential part of direct current motors) are so great that for many years the ordinary trolley voltage of 600 to 650 volts was regarded as the maximum practical limit for direct-current circuits on which motors were operated.

But since direct current is superior to alternating current for many conditions of light passenger railway service, and since low voltage currents can not be transmitted economically for more than a few miles, engineers have been constantly engaged in studying the troublesome problems in the use of high voltage direct current.

The first step in this direction was taken a few years ago, when several 1,200-volt lines were built. This voltage seemed daring at the time but soon proved completely successful. Last year saw the second step when a 2,400-volt line was developed.

The third step would probably have been another small and cautious one had not a group of railway engineers determined to do the thing right and prove the feasibility of a voltage that was really high; 5,000 volts was selected as the initial limit because, in the words of N. W. Storer, general engineer for the Westinghouse Electric and Manufacturing Company, builders of the equipment, "it is high enough to make it easily possible to collect current for the largest locomotive from an overhead trolley wire, high enough to lessen the amount of line copper and the number of sub-stations, and secure a good load factor and efficiency with reasonable cost."

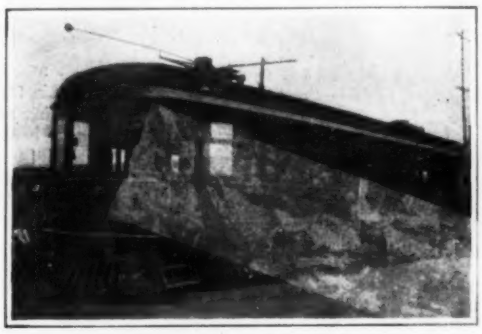
After the new equipment had been thoroughly tested, the Michigan United Traction Company offered to cooperate by giving the use of its 12-mile line from Jackson to Grass and Wolf Lakes for trials under actual service conditions.

The method of operation is as follows: During the day the regular 600-volt equipment handles the traffic, but late at night the high voltage current is turned on (the line having been specially reinsulated) and the last few trips are made by a special car. This car has been operating since June and so far not a single change has been found necessary in the equipment.

The ordinary type of generator is not used, but instead the current is taken from the present alternating current transmission line and transformed into direct current by mercury arc rectifiers similar in principle to the small outfits used for changing alternating current into direct for charging storage batteries and operating moving-picture arcs.

The motors of the car are of novel construction. As shown by the illustrations each has two armatures in a single frame, and two motors being arranged in series, each receives but one half the full line voltage. The operation of these motors has been thoroughly satisfactory; the commutation is perfect and flashing entirely absent. It is interesting to note that these motors operate on 600 volts while passing through the streets of the city of Jackson, the only change being in a few connections which are effected by the movement of a single lever.

An auxiliary circuit of 150 volts, supplied with the aid of storage batteries, furnishes current for the lights, air compressors, and control.



Michigan United Traction trolley car.

The double armature motor.

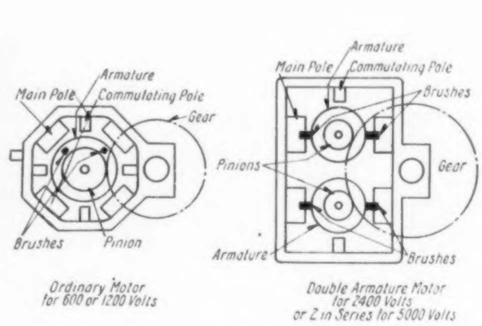


Diagram illustrating the motor.

Steel in the Light of Modern Research

ENGINEERS, as distinguished from metallurgists, may be pardoned if at first sight they fail to appreciate at its full value the excellent work which Profs. Arnold and Read have been conducting for many years now on the chemical and mechanical relations of iron and carbon with various of the rarer metals. A paper read before the Institution of Mechanical Engineers dealt with the influence of cobalt. This is the fifth element to be examined, the four others being vanadium, chromium, manganese, and nickel. One other, molybdenum, has yet to be discussed, and it is announced that this, the final portion of the research, will be ready for presentation in the autumn of this year. No engineer at this late date needs to be told that one of the profoundest and most significant discoveries of modern practical metallurgy was the quite extraordinary effect produced on steel by the addition to it of apparently insignificant quantities of one or more of the rarer metals. To these additions are due the wonderful properties of modern tool steel and of other steels without which the engineer would find many of his daring achievements impossible. Pure iron is almost a useless metal. Add a small percentage of carbon, with or without one of the rarer metals, to it and its entire properties are transformed. Notably, it is capable of being hardened and taking a cutting edge, a property entirely absent in the pure metal. To this day we do not know why steel hardens. No more do we know, as Prof. Arnold said, why diamond, quartz, or corundum is hard or why water is wet. Yet on this hardening property of steel our whole modern civilization may very reasonably be said to depend.

In studying this matter we are once again reminded of the very fine threads on which our life and civilization are hung. Because the axis of the earth is not quite perpendicular to the plane of the ecliptic, we get seasonal variations in the climate. Because ice is not quite as dense as the water from which it is formed, our seas and lakes freeze only on the surface and not solidly to the bottom in a mass that all the summer's heat might not melt. Because water is not quite incompressible, thousands of the earth's most valuable acres—2,000,000 square miles, according to a competent authority—are added to the land surface. Because iron has this peculiar property of hardening when carbon is added to it, we are enabled to cut and fashion metals and make them serve our will. As Sir Robert Hadfield reminded us, we cannot do without iron, the most wonderful metal in the world. It is admitted by all that of the other elements, nickel and cobalt are most nearly similar to iron, and that as shown by their position in the periodic classification and by a comparison of their properties, they are very closely related indeed to it. We are frequently led to believe that Nature works with methods distinguished by their continuity, that her progression is orderly. But it is not so always, and in this matter of iron, nickel and cobalt, everything is owing to a tiny erratic break in what is otherwise an orderly progression of properties. If the three elements are so closely allied, then it should be possible to form two "steels," neither containing iron. Sir Robert sought some time ago to surprise the world with the production of two such imitation steels. Taking nickel and cobalt he compounded them with carbon, as he would have done with iron had he been making true steel. But he found that both "steels" were quite incapable of taking the place of true iron-steel for any practical purpose. As soon as either was heated the carbon came out of the composition and was precipitated separately from the metal as graphite. As nearly as possible, iron would behave in the same way if we could imagine it in the form of tool steel, turning, when we tried to temper it, into cast iron. That would produce incalculable restrictions on the development of mechanical engineering and civilization as a whole. Yet it is only on the fact that steel when heated does not precipitate its carbon as graphite, a seemingly quite erratic departure on Nature's part from her orderly plan, that we are enabled to use it as we do. Prof. Arnold's researches confirm these views, and show, moreover, that even hammering nickel "steel" precipitates the carbon as graphite. On what delicate molecular bond, then, does true iron-carbon steel depend for its existence? We do not know at present, but such work as that of Profs. Arnold and Read is undoubtedly hastening the answer.

We have not forgotten that Prof. Arnold's view, as opposed to Sir Robert Hadfield's, is that there are three true steels. His researches show that by adding 5 per cent of vanadium to iron-carbon steel a true "steel"—vanadium steel—is obtained. In this there is no iron carbide present. This compound, well known to be indispensable in ordinary hardened steel, ceases to exist, and the carbon combines instead with the vanadium to form vanadium carbide. Unlike true iron-carbon steel, which hardens at 730 degrees or so, this vanadium steel does not harden until the metal is almost at the melting point.

When it does harden, however, it becomes as hard almost as carborundum. Again, by adding 11.5 per cent of tungsten to ordinary iron-carbon steel the carbide of iron ceases to exist, carbide of tungsten appears, and we get a true tungsten steel. In this case the hardening transformation starts at 850 degrees and is complete at 1,200 degrees. Interesting as these philosophical experiments may be, the chemical and mechanical relations of iron with carbon remain exceptional and indispensable to humanity. We may greatly modify or improve these relations by adding certain other metals, but no effort has yet succeeded or is in the least likely to succeed in discovering a substitute for iron. On the other hand, we have Nature endowing us with this metal in vast quantities and in a form easily recoverable by man. On the other, we find the whole utility of the element dependent upon some minute flaw, if we may dare to call it such, in the properties she has bestowed on it. For that flaw and the establishment of its existence we, as engineers, have every reason to be grateful.—*The London Engineer.*

Motor Fuels*

Vapor Tension and Other Characterestics of a Perfect Fuel

By Prof. Vivian B. Lewes, F.I.C.,F.C.S.

The gross heating value of a fuel is the total heat evolved by the complete oxidation of its combustible constituents, while when hydrogen is one of these it burns to water, the vaporization of which renders latent a portion of the heat evolved, and, if the steam escapes with the other products uncondensed, this heat is lost with it, and the net calorific value of the fuel is the total heat of combustion minus the latent heat of the water vapor formed.

In the internal combustion engine, the water formed by the combustion of the hydrogen of the gasoline all escapes as steam, so that it is the net calorific value that is the important factor.

In forming an estimate as to the value of a motor fuel, calorific value is by no means the most important thing to consider, as often it happens that the efficiency of the engine using it may be so increased, owing to the nature of the fuel allowing of high compression or other factors that tend to the better conversion of the heat units into power, that a fuel relatively poor in calorific value may be nearly equal to one of far higher thermal units in actual use.

There is, however, one point that always must be taken into consideration, and that is the vapor tension of a liquid intended for use as a motor fuel, as this governs its power of evaporation, and upon it depend ease in starting from cold and flexibility in running.

A good motor fuel must give off enough vapor at low temperatures to form an explosive mixture in the cylinders of a car that has been standing all night in a cold garage, as if it does not considerable time and much effort have to be expended in working the starting gear, so as to get a sufficient amount of combustion in the cylinder to raise it to the necessary temperature.

A good deal naturally depends on the form of carbureter used; but with any of fairly modern type a good spirit should give no trouble.

We have seen that when a crude oil is distilled the temperature is raised gradually, and that the fraction which comes over up to 150 deg. Cent. is called "benzine," and contains the most volatile portions of the oil. The next fraction coming over at from 150 deg. Cent. to 300 deg. Cent. is called "kerosene," and forms the ordinary illuminating oil. The lower fraction can be redistilled, and if the specific gravities and vapor tensions of these fractions be taken it will be found that the vapor tension falls as the specific gravity rises, as is shown in the following table obtained from the fractionation of an American oil:—

Specific Gravity.	Vapor Tension in Millimeters Water at 15 deg. Cent.
0.650	2,110
0.680	1,185
0.695	930
0.735	410
0.756	125
0.762	85
0.772	40
0.788	15
0.812	0

These figures make it clear that an oil of this last character, having a specific gravity of 0.812 (which would correspond to kerosene or lamp oil), cannot be used alone as a motor spirit, because on a day when the temperature was 15 deg. Cent. the engine if cold would never start, as no vapor would be given off to make the explosive mixture with air, and not only must vapor be given off but sufficient vapor to make an explosive mixture with the air in the cylinder.

The scientific methods of determining the vapor tension of a liquid upon which its volatility depends would be far too complicated for use by the ordinary observer; but he can form an equally sound judgment as to how far a motor fuel is likely to be satisfactory in starting and flexibility by means of a simple apparatus devised by Sir Boverton Redwood and Captain Thomson, whereby the relative volatility of various spirits could be determined, the object they had in view being the pressure the spirit might develop in a closed vessel on increase of temperature as bearing upon safety in storage and transport.

The apparatus consists of a thick-walled glass tube of small bore, about 30 inches long. The lower end of the tube is turned up and widens into a cylinder, about 6 inches long and 1 inch in diameter, the upper end of which terminates in a short length of glass tube. The long tube is graduated in inches divided into tenths, and the wide cylinder is provided with two marks, the lower corresponding with the zero of the scale and the upper being placed at nine-tenths of the capacity of the cylinder above the lower mark.

In use a short length of stout rubber tubing is wired to the tube at the top of the cylinder so as to cover it entirely and project about ¾-inch above it. Mercury is poured into the cylinder up to the lower mark, and care is taken that the mercury thread in the capillary tube is not broken. Enough of the liquid under test is poured into the cylinder to fill it well up to the upper mark, and the apparatus is clamped vertically in a vessel of water at 50 deg. Fahr. After sufficient time has elapsed to allow of this temperature being attained by the apparatus and its contents, the level of the liquid is corrected, if necessary, and the rubber tubing is closed by a pinch cock screwed up very firmly just above the top of the glass tube, the open end of the india-rubber tube being further closed by a glass stopper. The whole apparatus is immersed above the top of the rubber tube in water at 50 deg. Fahr. The temperature of the water is raised very slowly by means of a rose burner, and its temperature read by means of a thermometer immersed in it, unequal heating being avoided as far as possible by any form of mechanical stirrer. As the temperature of the water rises the height of the column of mercury in the capillary tube is read off at every 5 deg. Fahr. rise of temperature in the liquid, the heat being so regulated that this rise takes about ten minutes, and is continued to 100 deg. Fahr.

In this way, a comparison can be made between the vapor pressures of various suggested substitutes for gasoline as long as they are of the same kind of hydrocarbon, as we know that the best gasolines on the market, give only just the necessary starting power on a cold morning, and that anything that gives a vapor pressure less than that will give rise to trouble in starting, the pressure being a very fair measure of the trouble that would be experienced.

In the following table are given the pressures exercised by Pratt's "Perfection," benzol, alcohol, and pentane:—

VAPOR PRESSURE IN INCHES IN MERCURY.

Temperature deg. Fahr.	Pentane.	Pratt's Spirit.	Benzol.	Alcohol.	A.	B.
55	1.4	0.7	0.1	0.3	0.4	1.0
60	2.0	1.4	0.7	1.1	1.1	2.6
65	3.8	2.6	1.5	1.8	1.9	4.2
70	5.8	3.6	2.5	2.7	2.8	6.4
75	8.0	4.8	3.5	3.6	3.8	8.9
80	10.4	5.9	4.5	4.7	4.9	10.9
85	13.1	7.1	5.5	5.75	6.2	13.4
90	15.9	8.2	6.4	6.9	7.1	15.6
95	18.9	9.3	7.3	8.0	8.1	17.6
100	22.3	10.5	8.4	9.2	9.0	20.5

Taking the figures in the table, we know by experience that Pratt's spirit with an air temperature of 60 deg. Fahr. starts from cold without any trouble, and so also would the benzol and the two cracked spirits marked *A* and *B*, but nothing one could do would make the alcohol start at that temperature, although it is showing a higher vapor pressure than the benzol, and this is due to the percentage of combustible vapor in the mixture in the cylinder that will explode with electrical ignition. In the case of the benzol it needs only 2.7 per cent of vapor to give explosion, while with alcohol there must be at least 4 per cent, so that although its vapor pressure is higher than that of benzol it does not vaporize sufficiently quickly to reach the larger proportion of vapor needed.

When gasoline or other combustible vapors are mixed with air the maximum of chemical action—that is, the complete oxidation of the carbon and hydrogen of the combustible into carbon-dioxide and water vapor—gives the greatest energy of explosion. This point is a fixed and unalterable ratio of the vapor to air, and varies only with variation in the composition of the combustible body. On each side, however, of the percentage of vapor that gives the maximum effect there is a range over which the mixture is still explosive, although gradually diminishing in power the further the percentage of vapor is from the correct mixture, until points are reached above and below which the mixture is non-explosive.

The percentage over which the mixture is explosive is called the "explosive range," and varies slightly according to the method of ignition, and figures that have been given for electrical ignition are:—

EXPLOSIVE RANGE OF AIR-VAPOR MIXTURES WITH ELECTRICAL IGNITION.

	Per Cent	Range Per Cent.
Acetylene	3.2 to 52.2	49.0
Ethylene	4.2 to 14.5	10.3
Alcohol	4.0 to 13.6	9.6
Ether	2.9 to 7.5	4.6
Benzol	2.7 to 6.3	3.6
Gasoline	2.5 to 4.8	2.3

Although when ignited by a flame a still smaller proportion is combustible with explosion.

It is quite evident that the wider the range over which the spirit employed will form an explosive mixture, the more elastic will be the proportion of air, and we all know the trouble caused when a sudden change in heavy traffic stops the engine by throwing the mixture outside the explosive limits.

Another test which it is essential to make with a motor spirit is a fractional distillation, in order to ascertain the proportion of hydrocarbons present in it vaporizing at a sufficiently low temperature to ensure a complete combustion in the cylinder, and with spirit of the ordinary character 90 per cent ought to distill over below 150 deg. Cent.; but it must be remembered that this does not always apply to gasoline substitutes.

In carrying out a fractional distillation of this character great care has to be exercised in standardizing the method to be employed, as the results found by various observers in a fractionation of the same spirit differ widely, unless the same method of procedure and apparatus are adopted. Probably the most satisfactory method is to take a short-necked Jena glass flask, into the neck of which is fitted a five-bulb Young dephlegmator, in the top of which is placed a thermometer so arranged that the bulb is just below the level of the side tube. A uniform rate of distillation throughout the run must be maintained, and the temperature is noted at which the first drop leaves the end of the side tube. From that moment, the volume collected through each 10 cubic centimeters should be noted, and the distillation carried up to 150 deg. Cent., unless the bulk of the liquid has passed over below that temperature.

When distilling mixtures such as are to be found in some gasoline substitutes, the distillation results, if plotted out, will generally give a very good idea of what the constituents are, which can be confirmed by taking the specific gravities of the main fractions. In the following table the fractionation of Pratt's spirit is shown as an example of a true gasoline:—

FRACTIONATION OF PRATT'S SPIRIT.

Specific gravity	0.7088	
First drop	30°C.	
Below 50°C.	1.50	per cent
" 60°	7.25	"
" 70°	19.25	"
" 80°	28.75	"
" 90°	42.25	"
" 100°	57.25	"
" 110°	70.25	"
" 120°	79.50	"
" 130°	86.50	"
" 140°	91.00	"

It must, however, be clearly grasped that in many gasoline substitutes it is possible to use mixtures in which some fractions distill as high as 250 deg. Cent. if sufficient spirit distilling below 100 deg. Cent. is present to give ease in starting and the necessary flexibility in working.

When gasoline was first introduced it seemed probable that its high volatility, and the fact that the vapor it gave off was highly inflammable and formed a violently explosive mixture when mixed with air, might threaten its use, but experience has shown that the accidents due to it have not been nearly so numerous as it was feared they might be. One knows from experience that on a warm summer's day the vapor comes off so rapidly that a tin left open soon undergoes a serious diminution in volume, and that the spirit has such a wonderful penetrative power, and is so liable to creep, that the smallest fault in a screw-cap or plug leads to a slight leakage, with the result that in places where the gasoline is stored, slight leakage and evaporation into the air are constantly occurring, and as 2½ per cent of the vapor in the air forms an explosive mixture of maximum strength, while 1.6 per cent is still explosive when ignited by flame, strict precautions should be taken to protect such places from becoming an active source of danger. Probably the factor which gives the greatest danger is that the weight of the gasoline vapor is so far above that of air that it

* Abstract from a lecture delivered before the Royal Society of Arts.

spreads and flows over a flat surface in much the same way that a liquid would do, and as a pint of it poured on the floor will give sufficient vapor to cover 80 square feet with inflammable vapor to a sufficient thickness if ignited at any point to carry the flame back to the point of leakage, it is clear that the floor level is the one which should be specially considered in precautions to minimize danger, and a strong floor draught is one of the most important factors of safety that can be provided.

The reason why so few accidents happened in the past is due to the high temperature needed to ignite the vapor either alone or mixed with air, and a long series of experiments made in the early days of the use of gasoline showed that the vapor could not be ignited by the glowing spark on a splint of wood, a red-hot piece of coke, or a shower of sparks from a flint and steel; and from experiments which I have made since I think we may safely assume that the ignition point is in the neighborhood of 1,200 deg. Cent., and it is this which has safeguarded its use. How often have we seen the careless chauffeur filling the tank of his car with spirit while at the same time smoking a cigarette, a proceeding which, had the igniting point been as low as that of any ordinary combustible, such as paper, wood or coal, would have led to disaster.

The necessary temperature to cause ignition, although never reached by a glowing body, is attained with the smallest of flames, the temperatures of which are practically all higher than 1,200 deg. Cent., and the throwing down of a lighted match on a surface over which gasoline vapor is flowing has caused many serious fires.

The high ignition point of the explosive mixture of gasoline and air also explains the necessity for a higher density spark for igniting the mixture in the cylinder.

The volume of vapor yielded by a sample of gasoline depends upon its composition, the variation which exists between the various constituents being shown in the following table:—

VOLUME OF VAPOR FROM GASOLINE HYDROCARBONS.

	Specific gravity.	Boiling-point.	Cubic Feet of Vapor	
			Per Gallon.	Per pound.
Pentane	0.626	37.6°C.	31.2	4.9
Hexane	0.664	69°	27.7	4.1
Heptane	0.700	98°	25.7	3.7
Octane	0.719	118°	22.6	3.1
Nonane	0.741	136°	20.8	22.9

So that the higher the specific gravity the lower will be the gas yield.

The Zodiacal Light

Theories as to It's Cause, and It's Place in the Solar System

The theory that the zodiacal light is a nebulous ring surrounding the sun is, for the most part, no longer held. It was Baron von Humboldt's theory and Sir John Herschel wrote: "I cannot imagine upon what grounds Humboldt persists in ascribing to it the form of a ring encircling the sun." For dynamical and optical reasons we believe this theory to be untenable.

The theory that it is a solar appendage has received more support and in fact remains the theory most generally accepted. It was originated by Giovanni Domenico Cassini at the Royal Observatory, Paris, about 1685. But it is hard to conceive what form such an appendage can take reaching out from the sun to a distance exceeding the earth's orbit. At Pike's Peak in 1878 during a solar eclipse Professor Langley observed the long coronal streamers extending to a distance estimated at 10,000,000 miles, and the question has been asked: May not the corona in increasingly attenuated form extend 93,000,000 miles? Apart from the fact that the appearance of the Zodiacal Light does not correspond with that of the corona, Laplace declared that the sun's atmosphere "can extend no farther than to the orbit of a planet whose periodical revolution is performed in the same time as the sun's rotary motion on its axis, i. e., only $\frac{9}{20}$ of Mercury's distance from the sun." There is no evidence that the coronal streamers extend even to the orbit of Mercury.

Moreover, if the Zodiacal Light is a solar appendage of the kind supposed, reaching forth unbrokenly from the sun, it must create a resisting medium involving Mercury, Venus, the earth and the moon and of this there is no evidence. A variant of this theory invokes Arrhenius's doctrine of light-pressure, by which it is surmised that streams of electrons expelled from the photosphere are light-borne to a distance just exceeding the earth's orbit and there held in unstable equilibrium. This is a fanciful speculation and, without prejudice to the applicability of Arrhenius's doctrine to the relationship between solar electrical action and terrestrial magnetism, it may be stated that there is no evidence that the zodiacal light can be thus accounted for. The conception of a lenticularly-shaped envelope, which is usually connected with the solar appendage theory, arose in my opinion, from the lenticularly-shaped appearance of the zodiacal light as frequently observed. But this conception is rendered valueless by the fact that *the illuminated part of the Zodiacal Light band does not exhibit the whole of the Zodiacal Light band material at any one and the same time.*

The third outstanding theory to account for the Zodiacal Light is that it is an earth ring, comparable, say, to the "crape" ring of Saturn.

By using the word "comparable" it is not intended that the Zodiacal Light band corresponds *in every respect* to the crape ring of Saturn. Variety in similarity appears to be Nature's method. Saturn's ring system is situated in the line of the planet's equator. The Zodiacal Light band follows the line of the ecliptic and maintains with respect to the Sun's illumination a uniform appearance the year round, but as viewed by an observer on a fixed station the light changes in direction and intensity in the course of the year, according as the angle made with the horizon is more oblique or more nearly approaches a right angle. The points of resemblance suggested by the word "comparable" are (1) that, like Saturn's "crape ring," the Zodiacal Light band is a planetary ring and (2) that, like the crape ring, it is well-nigh transparent.

After the famous Leonid display of 1833, a discussion arose on the possibility of the Zodiacal Light being the origin of meteors. In the course of that discussion J. C. Houzeau contributed a paper to the *Astronomische Nachrichten* in which (as the result of his own observations) he argued that the causes of the Zodiacal Light may be "more local than has been hitherto supposed." A few months ago a well-known English astronomer, knowing of my interest in Zodiacal Light investigation, wrote me that no definite, stable results can be obtained concerning the place of the Zodiacal Light in the Solar System "until we have a continuous series of observations on both sides of the equator." Presumably he was not aware that such a series had been made. From April 2, 1853, to April 12, 1855, Sundays excepted, for every day of good observing weather, the Rev. George Jones, A. M., U. S. N., chaplain of the U. S. Japan Expedition, made observations of the Zodiacal Light. His report, comprising notes made at the time of each observation, accompanied by carefully drawn charts, was published by authority of Congress as a government document and forms volume III of the report of the U. S. Japan Expedition under the command of Commodore W. C. Perry. Under no better conditions could a series of observations possibly be made, and the length of time, extending over two years, in both the eastern and western hemispheres, north and south of the equator, from 41 degrees 50 minutes north (near Hakodadi, Japan), to 53 degrees 38 minutes south. (Straits of Magellan), permitted of as diversified a study of the Zodiacal Light as could be desired. Of the 328 observations reported and charted, 148 were made in the tropics. On each chart is marked the horizon line for each observation (sometimes three or four on the same evening or morning); the ecliptic line is marked, also the place of the sun on the ecliptic below the horizon showing the angle between the sun and the horizon; the outline of the stronger part of the light for each observation is drawn with reference to conspicuous stars or planets and a dotted line surrounding this shows the extent of what Chaplain Jones calls the Diffuse Light spreading North and South of the stronger band as far as he could see it.

Among other interesting special features of his report we note the shifting of the Zodiacal Light, as projected against the starry sky, from hour to hour; but always along the ecliptic; the gegenschein visible in the east in the evening; the Moon Zodiacal Light in the evening in the east prior to moonrise; the joint Sun and Moon Zodiacal Light, seen in the west in the evening, the moon being at first quarter; the simultaneous eastern and western Zodiacal Lights, seen in favorable latitudes, the cone of light reaching up from both east and west horizons about midnight, the eastern light growing stronger as the western light fails; the pulsations of the light due either to atmospheric conditions or to commotions in the Zodiacal Light band material; the varying brightness of the gegenschein sometimes well-defined, at other lines quite elusive and much elongated, due to change of angle of reflection in the course of the year.

While strenuously resolved not to begin his observations with any preconceived theory of the place of the Zodiacal Light in the Solar System, Chaplain Jones states that after a few month's observations, strive as he might, he could not banish the thought that it is an earth ring and this thought ripened into conviction by the time the cruise ended.

Present-day astronomers are generally agreed that the Zodiacal Light is at no great distance from the earth; that, as is said, there is something "familiar" about it. A careful perusal of Chaplain Jones's data, illustrated by his charts, leads one—no less than he was led when actually making the observations—to the conclusion that the theory of the Zodiacal Light being an earth-ring fits the facts more fully than any other theory. Especially the relation of the reflected moonlight in the eastern evening sky to the Zodiacal Light band; the presence at midnight of both eastern and western lights; the uniformly broad base of the light along the horizon, narrowing and sometimes tapering toward the observer's meridian circle; all of these facts considered in connection with the laws of the reflection of light argue a circularly or elliptically curved band at no remote distance from the earth, from which the light is reflected according to the angle of incidence.

Why, then, it may be asked, has not Chaplain Jones's conclusion won acceptance?

It is my judgment that the theory of a ring of nebulou or meteoric matter surrounding the earth was held u tenable because, if the Zodiacal Light band were such a ring, the light would be *strongest directly behind the earth*[1] as in the case of the full moon. It is, I venture to believe, this consideration which has led astronomers to reject the earth ring theory. Can this crucial objection be removed? It is unanimously conceded that there is a dimming of the Zodiacal Light directly behind the earth. At times nothing can be seen of it, at other times the gegenschein can be made out. The question naturally arises: Why is the Zodiacal Light dimmed (at times invisible), right behind the earth? My answer is: *The earth's shadow falls arthwart it.* The Zodiacal Light lies along the ecliptic—i. e. runs along the signs of the zodiac, the zodiacal constellations:—therefore, if within the range of the earth's shadow, it must thereby be dimmed. Lying on the ecliptic, the central part, so to speak, of the Zodiacal Light band is *exactly in the place of a full moon totally eclipsed.*

This, I beg to submit, is an adequate explanation of the reason why the Zodiacal Light is not strongest directly behind the earth. Accepting this reasonable explanation the crucial objection to the earth ring theory is demolished and the theory itself is strengthened to the point of demonstration. Further objection may be urged that if the Zodiacal Light band be an earth-ring the illumination should be strong and clear-cut right to the point where the earth's shadow intervenes. In considering this objection I suggest that allowance should be made for the penumbra secton of the earth's shadow which should have the effect of *diminishing* the brilliancy of the Zodiacal Light as it approaches the umbra. The persistence of the light through the penumbra and even into the umbra, though dimly and more narrowly, as reported from observations in the tropics seems to indicate that the Zodiacal Light material may be more agglomerated along the axis of the band.

On account of the feeble intensity of the light spectroscopic examination is very difficult and a specially designed spectroscope—such as Dr. Michie Smith's at Kodaikanal—is desired. Recent work by Professor Fath at Lick and Mt. Wilson corroborates previous examinations to the extent of affirming that the light is reflected sunlight.

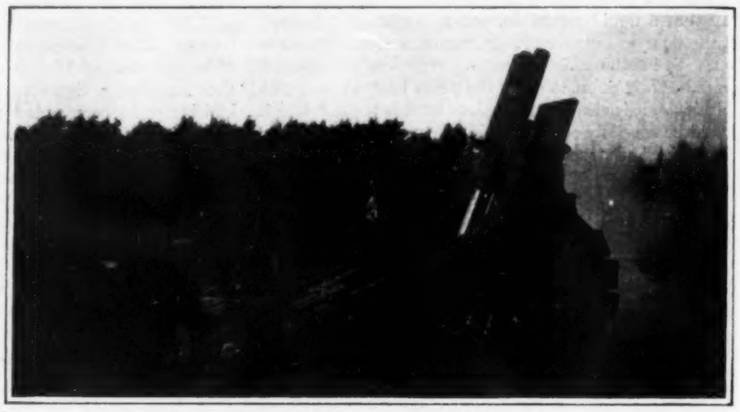
It may therefore be affirmed that the theory of the Zodiacal Light being a planetary ring is in good standing and that the preponderance of evidence is in its favor.—*Rev. W. E. Glanville in Popular Astronomy.*

Zeppelin Bombs

The incendiary bomb used by the Germans in their raids on London, as a rule, is conical, of 10-inch diameter at the base, wrapped round with tarred rope and having a metal handle at the apex. The base is a flat cup, onto which a pierced metal funnel is fitted, having the ignition device and handle fitted at the top. The funnel is generally filled with thermit. The latter, upon ignition, generates intense heat, and by the time of the concussion has taken the form of molten metal, having the extraordinary high temperature of over 5,000 deg. Fahr. The molten metal is spread by the concussion. Outside the funnel is a padding of a highly inflammable or resinous material, bound on with an inflammable form of rope. The resinous material creates a pungent smoke. There is generally some melted white phosphorus in the bottom of the cap, which develops nauseous fumes. In some cases celluloid chippings are added, and occasionally a small quantity of gasoline.

[1] By "directly behind the earth" is meant the point of the sky exactly opposite to the sun, e. g., at midnight.

Firing at a low angle of elevation.



A gun discharged at its maximum elevation.

Modern Heavy High Elevation Artillery*

New Structural Designs That Have Resulted from New Methods of Use

SINCE barrel-recoil mechanisms have been adapted to field artillery military experts have begun to develop mobile heavy ordnance, the value of which has been conclusively shown in the present war. The largest field artillery formerly used consisted of either flat-trajectory guns up to 15 centimeters (5.90 inches) and 30 caliber or howitzers ranging up to 28 centimeters (11.02 inches) and 12 caliber. The barrel weights did not exceed 2,600 kilograms (5,732 pounds). The howitzers used in the present war have barrels weighing as much as 3,800 kilograms (8,378 pounds), and are much larger caliber; examples are the Austrian 30.5 centimeters (12.007 inches) and the still larger German 42 centimeters (16.53 inches) mortar batteries. The use of such heavy calibers was made possible by re-designing the gun carriage to admit of the transmission of barrel recoil upon it. In the older types, either the carriage itself recoiled or it was mounted rigidly on a platform. The new design materially reduced the vertical component of pressure applied to the platform, in cases where the angle of gun elevation exceeded 60 degrees. It was found difficult to fire the heaviest howitzer without building a specially constructed platform, which required a great expenditure of time. This difficulty was overcome by the adoption of correctly designed wheeled carriages and by using a very long barrel-recoil. The vertical pressure upon the wheels, due to the high barrel elevation, was reduced, and therefore increased the durability of the wheels. High elevation guns possess higher muzzle velocities than long-barreled cannon. If howitzers were fired at the same angle as cannon, the strain on the wheels would be appreciably less, but they are fired at angles ranging up to 75 degrees as compared with 30 degrees for flat-trajectory guns, and a stronger wheel construction is necessary.

At a maximum elevation the breech is liable to strike the ground in recoiling, unless the trunnion is sufficiently high. French designers avoid a great height, even in cradle carriages, by excavating the ground between the carriage frames, thus allowing enough recoil space for the breech. A great trunnion height should not be used in portable guns, where the firing is mostly horizontal, or only slightly inclined; otherwise the gun becomes unsteady.

Artillery experts must adopt either rigidly supported carriages with short recoil, or wheeled carriages with longer recoil, which permit firing from cultivated ground. The purpose for which used and the topography and soil conditions of the territory are also to be considered. One illustration shows the type of carriage adopted for the 30.5 centimeters (12.007 inches) howitzer. Both systems differ so radically as to hardly permit comparison as to ease of hauling, readiness for firing or steadiness during firing.

The designers have laid stress upon a carriage construction which would be rigid and steady; but, in addition, the carriage should be easily moved and readily set up. The problem of transportation is difficult, as it is often necessary to haul loads of over 5,000 kilograms (11,000 pounds) upon macadamized roads and also on short stretches of cultivated soil.

The facility of transportation of heavily loaded vehicles is affected by ground conditions, by weather conditions, and by the unit load on the wheels. While the first two factors are variable, the load on the wheels for a given width is constant for each vehicle. The unit load may be reduced by increasing the axial width of the wheel. Formerly, strong planks were placed underneath the wheels. Corrugated rolled iron rails supplanted these. The designers next tried to reduce the unit load on the wheels by widening them in an axial direction. But traveling over artificial roads with wide wheels is difficult. A device was adopted which would allow the temporary increase of width, i. e., a section which could be clamped on or removed, according to the road conditions met. French constructors make use of pressed sheet steel quadrants which are fastened to the rim and spokes. These have the same radius as the wheels but have a greater axial width. This device did not prove to be satisfactory. The German practice of rim-widening is based upon a well-known Italian invention (Kriegst. Z. 1913). About 10 steel-covered, flat, wooden blocks are separately hinged to a closed ring on the circumference of the wheel, on the caterpillar plan. These blocks are about three times the width of the wheel proper. While French models have the advantage in light weight and rapidity of attaching the sectors, the German types are safe and dependable for all kinds of unfavorable soil conditions. Of course, the weight of such a wheel girdle is a large factor in guns of larger caliber—approximately 450 kilograms (1,000 pounds) per girdle—and this requires a special additional truck for transporting them. In both of the above types, the method of braking must be changed. The common method of applying the brake jaws directly to the rim is, of course, inapplicable. Instead, special braking discs are used, keyed upon the axle, or braking rings are screwed to the inner side of the wheel.

It is possible to double the contact surface by using an auxiliary wheel which revolves on the elongated hub of the main wheel as its axle, the hub being properly turned to a bearing surface. This double wheel possesses the French characteristics of silent operation, light weight and rapidity in setting-up; the wheel weight is only 190 kilograms (419 pounds) instead of 450 kilograms (1,000 pounds) when using a wheel girdle, and the girdle truck can be entirely dispensed with; and the well-known jaw brake can be used.

These devices are not only aids in the transportation of heavy guns, but are indispensable when firing. This is particularly noticeable in the case of howitzers. It had been found that, with the first barrel-recoil howitzers used, the recoil caused the wheels to sink into the ground. This could be prevented by laying planks underneath the wheels. However, these do not prevent a lateral movement after prolonged firing. The wheel-girdle system seemed to be more advantageous, and it has made possible the firing of large howitzers from wheeled carriages. Three or more blocks are in contact with the soil at one time, and these present a sufficiently large and flat surface to prevent any sinking in the soil and any lateral motion, because the blocks are attached to the wheel.

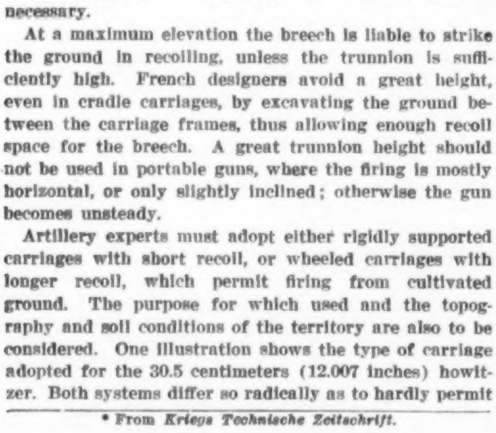
A long barrel-recoil reduces the stress on the wheels, and consequently the soil depression. Whether the wheel support of the girdle would prevent the depression in short-recoil, high-elevation guns will always be doubtful.

A carriage mounted on a solid platform possesses the advantage of greater rigidity, even in the case of short-recoil ordnance. The foundation effectually absorbs the lateral stresses without shifting. A more extended horizontal firing range is allowed—about 2x15 degrees sweep.

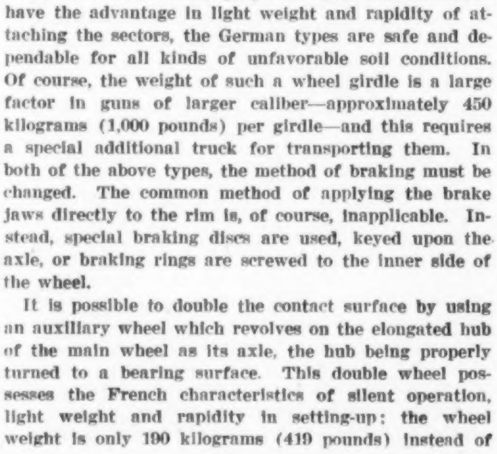
In the wheeled-carriage type lateral movement may be compensated for by swinging the carriage through small angular limits (about 3½ degrees to either side). For every shot fired with the deflected gun a lateral stress arises, which tends to swing the whole gun sidewise around the spur. This stress, and the lateral deviation, varies directly with the increasing angle of deflection. When this angle has reached its maximum, or a new target in the horizontal range is chosen, it is because the heavy anchoring spur is loosened. With high elevation guns the lateral deviation is not so great, as the lateral-thrust component is much less.

Quick preparation for firing is important, especially rapidity of erection. Owing to the great weight, the guns are divided into three parts for transportation. The train consists of a barrel-truck, a foundation or wheel-girdle truck, and the carriage itself. Very simple appliances must be used in assembling the gun, since this task, which is slow at best, will be further hampered by unskilled troops and unfavorable soil conditions. The wheeled-carriage can be run into position with its girdles, the barrel attached, the spur fitted, and the gun is ready for firing. The cradle type requires the tedious operation of constructing the foundation before the cradle and the barrel can be attached.

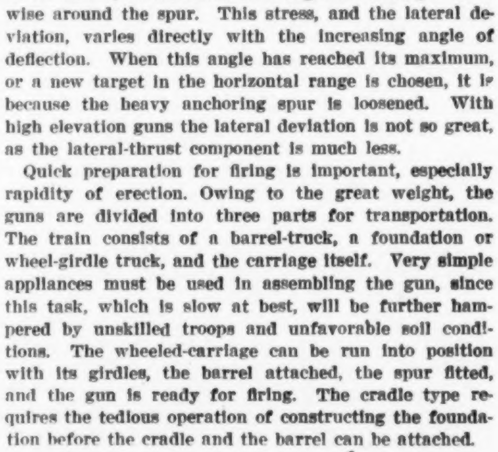
* From *Kriegs Technische Zeitschrift.*



A big howitzer loaded onto the truck by which it is transported.



Firing carriage of a big gun, showing recoil compressors. Note steel mat under the wheel.



Transferring the gun from the transport truck to the firing carriage.

A sweet gum grove in Tennessee.

A growth of young sweet gum trees.

Gathering Storax from the Sweet Gum Tree

An American Substitue for the Imported Drug

Owing to the war in Europe a great many drugs can not now be obtained, and in a number of cases the prices are from three to four times higher than those which prevail during normal conditions. The American trade depends almost entirely upon Europe for many of its crude drugs, and now since the supply has been cut off many people in this country are writing to drug houses for quotations on certain crude drugs which they are able to supply. From the East and South come a number of inquiries in reference to storax, which is the balsam obtained from the sweet gum tree (*Liquidambar styraciflua*). The storax which comes chiefly from Europe is obtained from a closely allied tree (*Liquidambar orientalis*), but during recent years the balsam of the American sweet gum has also been gathered and used to some extent in the preparation of chewing gum, and as a substitute for the European storax. The balsam from both of these trees is recognized and included in the United States Pharmacopœia.

Whether the gathering of this balsam in America will prove remunerative to the collectors has not been determined. The business of collecting crude drugs in this country is in most cases not a profitable one, because it is followed largely by the poor class in the rural districts, who prefer to earn 50 cents a day in this way than to receive three times as much at some steady employment. Up to the present time it has offered very little inducement as a means of earning a livelihood, chiefly because the product is disposed of at too low a figure. The material gathered is invariably taken in trade by the proprietors of country stores, who examine, grade and press it into bales suitable for shipment. In this way the wholesale drug houses receive a large part of their supplies at a very moderate cost.

In the case of storax, these conditions do not wholly obtain, because the process of gathering it is different and requires some knowledge and skill in properly conducting the various operations. At the same time the collector is dealing with a plant that has a commercial value, either present or future, for other purposes, such as fuel or lumber, and can not be had merely for the trouble of collecting it, as is the case with Virginia snake root of the fence corners and the golden root along the streams. The collector is required to gain permission, through purchase or otherwise, before he can operate on a tract of forest land that has on it a sufficient number of trees to make his enterprise a profitable one.

There are at present no well defined methods for collecting storax in America. The following facts relative to the European method may be useful to those who are interested in the collection of this balsam in the United States. The storax produced in Europe is the exudation of the oriental sweet gum tree and is obtained by injuring the young wood, which causes resin pockets to be formed in the growing tissue between the wood and the bark. The early descriptions of the methods followed in Europe do not agree, but it is now known that the product is pathological, rather than physiological, and in all cases the bark must be damaged sufficiently to stimulate the cambium to greater activity and to develop secretion cells in the wood and inner bark surrounding the wounds. The young trees are usually wounded when growth first starts early in the spring, and during the late fall the inner bark and a thin layer of the sapwood are then scraped off by means of a sickle-shaped knife, collected in bags and later boiled in large copper kettles. The balsam or resin-like substance soon rises to the top, and after it is skimmed off the water is removed and the bark placed in horse-hair bags and subjected to pressure, thus extracting the remaining balsam. In parts of the Orient the bark is then dried and used for fumigation. The product is at first a semi-transparent or honey-like liquid, but upon exposure and cold it soon becomes thicker or even hard, brittle, and almost opaque.

In the Eastern and Southern United States, where the sweet gum tree finds its best development, the balsam has been collected for a number of years in a more or less crude fashion. Large trees are often completely girdled in early spring in order to induce the production and flow of balsam, which oozes out at the junction of the bark and wood, where it collects in large yellowish tears or drops with a consistency of thin honey. These drops which soon turn hard and have a peculiar, agreeable balsamic odor and a bitter, warm and acrid taste, are collected during the late summer. The trees thus treated will die in the course of a year, and unless this operation is followed at once by the lumberman it will result in the waste of a great deal of valuable timber.

A knowledge of the practice of gathering balsam in Europe and Asia Minor, and a familiarity with the habits of the sweet gum tree in the United States, suggest an improved method for collecting the balsam, which seems far more practicable than the one now in vogue. The attention of the collector should be directed to the young trees, not alone because they grow more rapidly and produce balsam in greater abundance than old ones, but because the young trees occur very plentifully in all open places in the forest and in abandoned fields, and only relatively few of them ever grow up to be merchantable timber trees. The great majority of them succumb to inimical conditions before they attain a diameter of 4 or 5 inches, and should be made the chief source of balsam.

The method which seems most feasible to follow is to make shallow cuts or hacks into the stems and larger branches of the young trees until they are full of wounds. This should be done in early spring, and in the fall of the same year the bark and the wood laid on during the last summer may be removed by means of a draw-knife and the balsam expressed in the manner followed in Europe. Young trees sprout readily from the stump, and the sprouts surpass the seedlings in rate of growth. By proper cutting and management it would be possible to practise regular rotation cuttings.

Although the inner bark of the sweet gum is not official, it is collected and sold by botanical druggists because it contains an astringent gummy substance. In the southern and western states the bark of this tree is often used with asserted great advantage in checking diarrhea and dysentery, especially in children. It is considered a most valuable household remedy when it is boiled in milk or water and used as a tea. At one time it was regarded by a good many Southern physicians as one of the most useful mucilaginous astringents. The leaf of the sweet gum tree has no recognized medicinal or other value, but the green leaves are known to possess a high percentage of tannin.

The "Wolf Note" on String Instruments Played with a Bow

In the *Proceedings* of the Cambridge Philosophical Society (England), Mr. G. W. White describes some investigations in relation to a peculiarity found in all stringed musical instruments that are played with a bow. On all stringed instruments of the violin type a certain pitch can be found which it is difficult and often impossible to produce by bowing. This note is called the "wolf note," and usually occurs at an interval of an eleventh or twelfth above the lowest note of the instrument. At this pitch on either string the bow refuses to "bite," and a soft pure tone is almost impossible to obtain; if the pressure of the bow on the string is increased the tone resulting is usually of an unsteady nature with considerable fluctuations in intensity. It was thought that an analysis of the vibration of the belly of the instrument for frequencies in the neighborhood of the "wolf note" would settle the question of its origin, as to which there is considerable disagreement among musicians. The instrument selected for test was the 'cello. On such instruments the imperfect note is usually very pronounced, especially when played high up on the G-string.

The vibration of any part of the body of the instrument was recorded as a line on a moving photographic plate by reflecting a beam of light from an optical lever, one leg of which rested on the vibrating surface. Proceeding by steps of a quarter of a tone, it was found that as the wolf note was approached the vibration curve was much simpler and the amplitude considerably larger. It thus appeared that the pitch of the wolf note was about that of best resonance of the belly. This view was confirmed by eliciting these belly vibrations in response to the same note blown on a cornet with its bell near the belly of the 'cello. Further, by receiving the trace on a long film on a drum, and bowing the instrument, the fluctuations of intensity were shown to correspond to a waxing and waning of the belly's vibrations or the phenomenon of beats.

Variable Resistance Helical Spring Gear

It is well known that in the ordinary cylindrically-coiled helical spring compression is approximately directly proportional to the load applied, and while this is often an advantage there are many cases where it is desirable to have the resistance increase with the pressure. This is accomplished by an arrangement described and illustrated in *Engineering*, and in its simplest form consists of two helical springs separated by a pair of flanged ferrules, cut in such a manner that they pass through each other, and are provided with end stops. During the first part of the compression the two springs are in series, and act as one long spring, but as soon as the stops come together the two short springs act in parallel, and the resistance to compression increases, and before any further deflection can take place the load must be doubled. In this stage the two springs separate from each other at the center when further compressed.

Combustion of Gasoline

The range of complete combustion of mixtures of gasoline vapor and air is very narrow, according to an investigation made by the Bureau of Mines, which showed that it was limited to mixtures containing only between 1.5 and 2.5 per cent. The amount of carbon dioxide produced reaches a maximum at 2.5 per cent of gasoline vapor. At this point, as the percentage of gasoline vapor increases, carbon monoxide begins to form. At 4.1 per cent of gasoline vapor there is produced 14.0 per cent of carbon monoxide.

Economies in Operating Small Cars*

Solving New Problems of Local Transportation

By J. F. Laying

Railway managers have ever present before them the problem of balancing their expenditures with the receipts in the efforts to attain the proper operating ratio of expense to earnings. Of late years, due to general conditions, this problem has been harder to solve than formerly. It has been almost universally impossible to secure a change in the rate of fare, regardless of the advance in the rate of change in the cost of producing transportation. In past years it was possible to increase the total receipts by fare zones, or by decreasing the transfer privileges, but at the present time, in most cases, the attitude of the public to the public service corporation is that if reduction can be made in the charge for transportation the public is entitled to a reduction, but if for any reason whatever the cost of producing transportation is greater the public usually give the railway companies very little consideration, and generally the statement is made that the management of the property is inefficient.

In nearly all cases for city service the fare unit has remained the same, but it is also true that the average passenger haul is longer and the transfer privileges have had to be extended. The public have been educated to expect more and more from the transportation companies, not only in the grade of transportation given, but also they expect a lower rate of fare. In the early days of electric railways, small light weight single-truck cars with longitudinal seats and non-heated cars were looked upon as a luxury, but now the public expect large double-truck cars with comfortable transverse seats, and during the winter time the cars must be kept at a uniform temperature.

To meet the demand of the public and keep down the expense of operation, it is best for city service to run cars at the fastest practicable schedule speeds. With the large double-truck cars, naturally the total weights and weight per seated passenger are increased. These features naturally increase the wear and tear on the track and special work, and also increase the power consumption proportionately. The heavier cars also naturally require heavy roadbed construction with heavy rails, and even with the larger first expenditure for roadbed the heavier cars greatly increased the maintenance of way cost.

The rapid development of the automobile and its continued increased use has greatly cut into the receipts of both the interurban and city roads. During the past two years a large number of managers of interurban properties found the receipts during county and state fairs were greatly reduced when compared with former years. This reduction was attributed almost entirely to the increased use of the automobile.

During mild seasons of the year the automobile is and will probably continue to be a factor to be considered in the receipts of the short hauls of the interurban road. The cost of this method of transportation is higher than that furnished by the electric road, but with the class of person who owns and maintains a machine, even though it costs a little more, provided the expense is not continuous, it is not considered serious, and the pleasure of driving one's own car is considered to cover the difference. To meet this form of competition, many think the only thing to do is to bring to the attention of the automobile users the difference in the cost of the two classes of service, and to make the car service as attractive as possible. The city lines have recently encountered much more serious competition in the jitney. This service has developed almost over-night, and within an incredibly short period of time many railway companies have encountered a competitor that reduced their gross receipts 5 per cent, and in some cases 20 per cent. The jitney, as operated at present in most cities, follows the lines which have the most traffic. In a city where seven city lines are operated, only two of these lines were having jitney competition. One of the lines during non-rush hours gave a six-minute service, and during the rush hours a three-minute service, the other line gave a ten-minute non-rush hour and a five-minute rush-hour service; the other five lines gave a fifteen-minute service. With the two lines having the dense traffic the gross receipts dropped 20 per cent. Problems such as this put the railway management in a most serious position. The problem is not confined to any local community, but is a general one encountered from the New England States to the Pacific Coast. The general consensus of opinion regarding the jitney service is that there are three things which influence the public to use them; first, the high schedule speed; second, the novelty of the ride; and third, the direct delivery to the point of destination. It is also generally believed, from the experience of a large number of people, that the jitney service as given at present is not profitable, and that in its present form the service will not continue and is merely a passing fad. However, many believe that some form of the auto bus carrying possibly from ten to twelve passengers will be worked out, and may prove a really serious competitor for the electric service as it is now given.

The American railway men in the past have proved progressive, ingenious and resourceful. Every problem of maintenance and operation is scientifically studied, and the results of these studies are put into practice. There has been more originality and progress in transportation methods, car design and design of apparatus for this class of work than in any other business we have. With the art in such able hands and with the assistance of the technical press, which reaches us all at regular intervals, there is every reason to feel confident of the practical solution of the problem.

To get a proper perspective as to what is involved, a study of the figures given by the United States Census Bureau for the distribution of expenses of all the electric railways in the United States is of considerable assistance. This table gives the following ratio of costs to operating revenues:

General expense	9.53 per cent
Power	9.0 per cent
Maintenance of way and structure	8.17 per cent
Maintenance of equipment	7.06 per cent
Transportation	24.42 per cent
Total	58.18 per cent

In looking over these figures, it is but natural that the largest figures should be selected first for analysis; that is, the cost of conducting transportation, which is 24.42 per cent of the gross receipts. Practically all of this represents expenditures for platform wages. With the present plan or system of fare collections for the larger cities, and where travel is heavier, there does not seem to be any way of materially reducing these figures. All of the progressive railway companies have studied their local conditions and have increased schedule speeds to the maximum in order to secure the lowest possible platform expense per car mile. Cars have been designed with entrances and exits especially adapted to facilitate rapid loading and unloading, so as to reduce the length of stop to a minimum. In several cities skip-stop service has been inaugurated to cut down the number of stops per car on lines where a large number of stops necessarily have to be made. Curves shown in Figs. 1 and 2 illustrate the effect of increasing the length of stop with different stops per mile with cars geared to a free running speed of 20 and 25 miles per hour. These curves show the highest possible schedule speeds that may be obtained on level track under favorable conditions. When making calculations and considering practical schedules, it is best to increase the running time by 10 per cent to allow for the naturally slower schedule speed which will be caused by curves, grades, and obstructions by vehicles which are encountered in actual service.

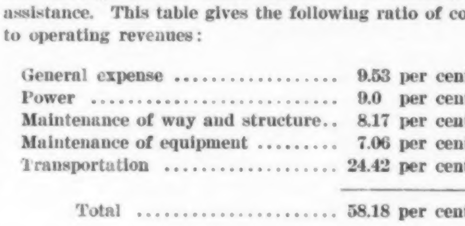


Fig. 1. Typical Schedule Speeds for 20-ton Car Geared for 20 m.p.h. max. speed Acceleration 150 lb. per ton Braking 150 lb. per ton Coasting 20 per cent power on period

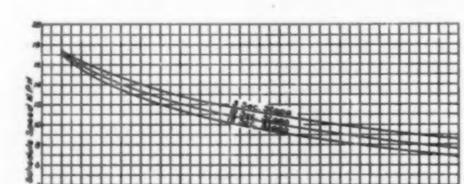


Fig. 2. Typical Schedule Speeds for 20-ton Car Geared for 25 m.p.h. max. speed Acceleration 150 lb. per ton Braking 150 lb. per ton Coasting 20 per cent power on period

A practical example of what long stops mean can be seen by referring to the schedule speeds. Let us take for example a line having a schedule speed of 12 miles per hour with six stops per mile and five-second stops. By increasing the length of stop to 15 seconds the schedule speed is reduced to 10 miles per hour. This is a reduction in schedule speed of 16⅔ per cent. Of course, extending the length of stop to 15 seconds for city service is a larger value than will be found normally, but it illustrates the value of the efforts to keep down the length of stop. By expending energy along this line, we can secure true economies as the increase in schedule speeds obtained in this manner do not require increased power per car-mile and will give us a greater number of car miles per hour. All railway companies have lines on which only one to five cars are operated and give sufficient service, and in some cases the combinations of the running time and distance will not admit of much change in present methods, but the cases where some possible saving cannot be made are comparatively rare.

The length of stops has been discussed at considerable length as it directly affects our problems of fare collection, general car designs and schedule speeds. There are many instances where one-man cars are now successfully used, and there will no doubt be many of these cars in the future. They will probably ultimately be used for practically all service, in cities having a population of 60,000 or less, and in large cities for lines on suburban sections where the traffic is not sufficient to warrant the use of the larger cars such as are used for a heavily congested traffic. In this class of work the light weight one-man car should serve the public equally as well as the larger cars.

With all of our present systems of fare collections, it is necessary for the operator to handle money, and as long as this is true, it would hardly seem practicable to have the cars in the larger cities operated by one man. The additional time which would be consumed by making change and giving transfers would probably prove too great a handicap. These features with the larger number of cars required would extend schedule speeds and cause obstruction to traffic in the down town section. Therefore, unless we have some radical change in our fare collection and transfer feature for larger cities the only way to change the traffic expense ratio is by having each car operated so as to run the maximum car miles per hour. However, in a small city and on many suburban feeder lines, large savings are possible with the small car. Those who have made a study of the one-man car deem it advisable to have all the possible safety features, which includes "dead man's release" on the controller, which when the operator's hand is removed from the controller handle, automatically cuts off current from the motors, sands the track, applies the brakes, and when the car comes to a full stop opens the car door.

Again referring to our census figures, we find that the next highest item is power, which constitutes 9 per cent of the total. There are three ways to reduce this figure, which are reducing car weights, slowing down the schedule, and more efficient operation. By more efficient operation is meant savings that can be made by operating at the proper rate of acceleration, maximum coasting, and proper rate of braking. The question of saving power by lengthening the schedules can hardly be considered, as the savings made by this method for city service almost universally are considerably less than is necessary to balance the extra cost of transportation expenses.

For the purpose of the present discussion, it will be assumed that all possible savings are being made by the proper application of power and brakes. This will confine us entirely to the question of car weights. The

* General Electric Review.

influence of the actual cost of transporting a given weight varies greatly. Some railway officials say that it is a negligible figure and do not consider that a few hundred pounds more or less on the car affects the cost of operation; while others figure that it costs 30 cents per year to carry an extra pound. The generally accepted figure of five cents per pound per year has a good deal of justification. However, the only tangible figure is that for power. All other elements entering into consideration are more indefinite. Recently an analysis of the service of a large city line where the maximum schedule speeds are operated showed the power consumption at the power house to be 170 watt-hours per ton-mile, and the average miles for a car owned is 40,000 per year. Current costs this company 0.7 cent per kilowatt-hour. It can, therefore, be seen that for current alone the cost of hauling one pound per year is 2.38 cents. There are of course other expenses that increase with weight, such as larger investment for power supply, feeders and extra cost of the maintenance of right of way, due to the increacsd weight to be carried.

When considering power alone, savings can be made almost in proportion to reduction in weights of cars.

When the successful storage battery cars were put in operation, a great object lesson in car body and truck construction and electrical design was given to the equipment designers in this country.

One of the next steps was the realization that two-motor equipments will give satisfactory service where grades do not exceed five per cent and where trailer operation is not required. However, there are many American cities where grades exceed five per cent, where two-motor equipments are far from satisfactory.

One of the next greatest advances was made by Mr. P. N. Jones and his assistants when they put 24-inch wheel equipments in service on the Pittsburgh railways. With these cars and other cars of this character which have since been built, the weight per seated passenger was decreased to approximately 600 pounds, while the preceding types of cars using four-motor equipments had a weight equal to 900 or 1,000 pounds per seated passenger. With the small diameter of wheel smaller truck strains are obtained, which coupled with the less weight of wheel gives us trucks which are roughly speaking 33⅓ per cent lighter than the trucks which were formerly used for this same class of service. Since the Pittsburgh railways put in service cars with 24-inch wheels, a number of other companies have also purchased the same class of equipment, and all indications now are that an entirely new field of development has been started by the small diameter of wheel. With single truck cars it is possible to have a much longer wheel base with no greater binding in curves than is obtained with a relatively short wheel base with a large diameter of wheel.

Recently the jitney competition has caused operators to again review general car designs to determine if it is feasible to develop a light weight one-man car. Mr. J. M. Bosenbury, Superintendent of Motive Power of the Illinois Traction System, has designed a single-end and double-end one-man car; each of these cars seating 30 passengers. The single-end car completely equipped will weigh 10,000 pounds, and the double-end car 15,000 pounds. These weights are equal to 333 and 500 pounds, respectively, per seated passenger.

Mr. C. O. Birney of the Stone & Webster Engineering Corporation has designed a single-end one-man car which will weigh completely equipped 9,000 pounds and seat 29 passengers, which is equal to 310 pounds per seated passenger.

In some cases these types of cars might advantageously use motors smaller than we are now considering standard for railway service, but if there is a real demand for this class of car, and if it is ultimately believed by the transportation interests that such a car is desirable, the manufacturers of apparatus can be depended upon to supply equipments which will meet the requirements in every respect.

Again referring to the census figures, the next item which we have to consider is 8.17 per cent for maintenance of way and structures. Of course, with very light cars this figure will be reduced, but as the amount of the reduction is difficult of determination, a direct answer could not be given to this question, as it would vary greatly with different localities and different conditions.

The next figure from the census report is 7.06 per cent for maintenance of equipment. The maintenance figure would be reduced with the small light weight cars from 10 to 20 per cent.

All that have been discussed previously in this paper have been features which enter into the design of our present cars and those things which may be considered when designing the small one-man car. From a purely engineering standpoint there is not the slightest doubt but that the small light weight one-man car should be used for practically all service. With the small car when compared to larger cars used at present practically the same service can be given with at least 18 per cent less expense; that is, when operating a one-man car and in giving service that is required in many cases.

For a direct comparison of power, with different number of stops per mile and different car weights, a curve

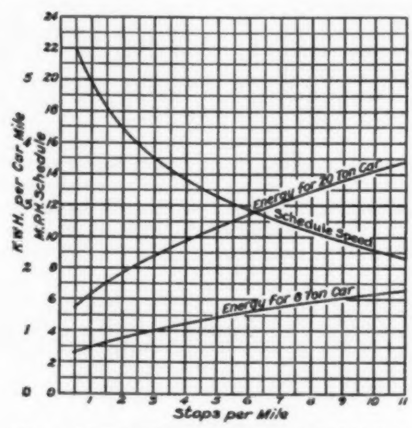


Fig. 3. Curves showing Energy Saving with Light Cars for Various Stops
Free speed 25 m.p.h.
Four-motor, 20-ton car—friction 24 lb. per ton
Two-motor, 8-ton car—friction 30 lb. per ton

showing the energy for an 8-ton and a 20-ton car is shown in Fig. 3. The 20-ton car includes the live load and therefore a four-motor equipment is favoring the larger car to a considerable extent, while the 8-ton car is showing the small one-man car up in as unfavorable a light as could be consistent insofar as power calculations are concerned. In order to help arrive at an understanding of the advantages and disadvantages of a one-man car, an example has been taken of a line which is 10.6 miles per round trip; the running time for the round trip one hour, with six stops per mile. Platform wages for the two-man car are taken at 50 cents per hour, for the one-man car 30 cents per hour, and the power is assumed to cost one and one-half cents per kilowatt-hour delivered to the car. The present cars seat 48 passengers and the proposed one-man car seats 32 passengers. The power as shown by the curve for a 20-ton car for this service would be 2.9 kilowatt-hours per car mile at the car, and for the 8-ton car 1.3 kilowatt-hour. The receipts for the present cars are assumed to be 24 cents per car mile.

For the one-man car two grades of service are analyzed, viz.: one in which the headway during the non-rush hour is decreased from the present service of ten minutes to six minutes, and the second in which the interval between cars is left the same as at present, but giving during the rush hours an increased service the same as would be required with the one-man car frequent service.

	Present Car Seating 48	Proposed One-man Car Seating 32	Proposed One-man Car Seating 32
Headway for 14 hours	10 min.	6 min.	10 min.
Headway for 4 hours	5 min.	3 min.	3 min.
Running time	60 min.	60 min.	60 min.
Cars required 14 hours	6	10	6
Cars required 4 hours	12	20	20
Seats per hour 14 hours	288	320	192
Seats per hour 4 hours	576	640	640
Car miles per day	1399.2	2332	1738.4
Power	$40.57	$30.31	$22.60
Platform wages	66.00	66.00	49.20
Maintenance of way 8.17 per cent	27.43	27.43	27.43
Maintenance of equipment 7.06 per cent	23.69	23.69	23.69
General expense 9.53 per cent	32.00	32.00	32.00
Total expense	$189.69	$179.43	$154.92
Receipts at 24 cents per car mile	335.80	335.80	335.80
Ratio of expense to gross receipts, per cent	56.5	53.5	46

The above analysis shows the receipts the same for all classes of cars. The smaller cars in both cases give much more frequent service, and it is but natural with this increased service that the receipts should be greater. With the large car the operating ratio of expense to gross receipts is 56.5 per cent, while with the small one-man car with cars at six-minute intervals instead of ten-minute service, the operating ratio is 53.5 per cent.

Reviewing the figures of the one-man car giving ten-minute service during the non-rush hours and three-minute service during the rush hours brings out several very prominent facts. The first is that the operating ratio has decreased to 46 per cent. The second is that with this type car more seats per hour can be furnished during the rush hour with 18 per cent decreased expense. Another fact is that during the non-rush hours the larger seating capacity of the larger cars is not required. In many cities the average load does not require more than 50 per cent of the seating capacity furnished. With the small cars the seating capacity during the non-rush hours is in the proportion to the logical actual requirements and conforms to a natural and proper saving.

It will be noted that expenses for traffic other than platform wages are left the same for the one-man car as for the proposed car as it would hardly seem fair to the small car to do otherwise. It is also assumed that the extra car miles which are made by the small car will offset any savings in maintenance of equipment and track, and the same proportions of expense have been used as have been found by the average throughout the country.

Certainly it would seem from these figures that in the future many light weight one-man cars will be purchased.

In many cities there are ordinances or rulings of public service commissions which at present prohibit the use of one-man cars, but it is reasonable to assume that when the case is properly presented, and if the light weight car will serve the needs of a community, these restrictions will be removed.

Explosibility of Mixtures of Natural Gas and Air

The Bureau of Mines has determined the explosive limits of mixtures of air and the natural gas used in Pittsburgh, this gas being typical of that supplied to many cities. For most practical purposes these limits may be accepted as applying quite closely to practically all the natural gas mentioned in this paper.

The limits were determined in a Hempel explosion pipette over mercury. Ignition was brought about from above by means of a small electric spark from an induction coil, driven by four dry cells. The smallest quantity of natural gas in a mixture of natural gas and air that upon ignition completely inflamed as observed by the eye was 4.92 per cent. The largest proportion was 11.50 per cent. In its determinations of explosive limits of methane-air mixtures the Bureau of Mines has found that large containers (130 liters capacity) and ignition from below with a large electric flash give wider limits than a small vessel and ignition from the top. In the case of methane-air mixtures the difference on the low limit was 0.5 per cent, this is probably true of natural gas-air mixtures; in other words, instead of 4.92 per cent natural gas being the low limit, under other conditions the limit may be as low as 4.50 per cent. The upper limit is undoubtedly extended as much.

For most of the samples the amount of air required for complete combustion varies but little. One cubic foot of pure methane requires 9.5 cubic feet of air; 1 cubic foot of the natural gas used in Pittsburgh requires 10 cubic feet of air.—*Technical Paper 109, Bureau of Mines.*

Electro-Photography of Coins or Medals

According to *Electrotech. u. Maschinenbau*, photographic negatives of coins, or similar objects, can be readily obtained by the following method: An ordinary photographic plate is placed film side up on a sheet of metal; the object to be photographed is then placed in contact with the emulsion. Wires from the poles of a high-tension transformer giving a minimum p.d. of 5,000 volts are connected with the coin and metal plate, respectively. The explanation of the results obtained appears to be that a glow discharge occurs between the two metallic disks, which are separated by the glass of the photographic plate, and that the generation of ultra-violet rays accompanies this discharge. These rays decompose the silver bromide. Those parts nearest are subjected to strongest action, and *vice versa*, hence a half-tone image results.

Suggestions in Mechanisms

What Can Be Done With a Circular Saw

By Samuel D. Mott

It is ofttimes instructive to observe how very usual things can be done in unusual ways, and thereby hangs many a tale exemplified in mechanisms. The common implement or method may be adapted to attain unusual results by indirection. As a concrete instance there is much time and money saved to quarry owners of slate, marble and other products by sawing out the raw material with a steel cable supplied with grit mingled with water. The breakage is thus minimized and a large percentage—frequently as great as 80 per cent—is saved from what otherwise is not only material waste but an expensive nuisance. It is one of many instances of common process treated by novel and efficient method.

Fig. 1 Fig. 2.

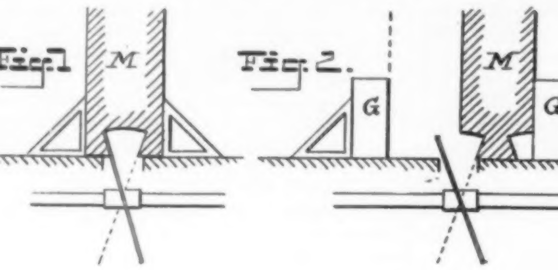
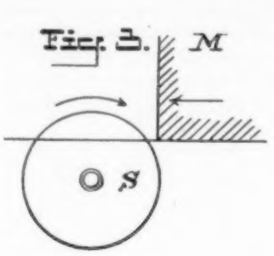


Fig. 3.



In the School of Science at Princeton in 1879 the writer had use for a jig-saw that would make a neat clean cut for some special work in the Physical Laboratory. At that time jig-sawing was a popular fad indulged in by amateur fancy workers in wood. These handy tools went by the common name of scroll saws. I made that jig-saw blade for a special purpose with a double cutting edge—teeth on both edges—and it did superior work, and was a time saver. It would run in and out of acute angles consisting of straight lines or any curvatures or configurations without scarifying the edges or marring the neatness of the cut, as was always the case when the running saw was used as a pivot around which the material was revolved in giving new direction to the cut. With a double cutting edge this was totally avoided. It has frequently occurred to the writer a strange thing that the band saws so largely used in industrial establishments are not made with teeth on both edges. It would be a time and labor saving expedient to saw the material through one way and back the other.

As an instance of utilizing implements by indirection, it would be difficult to find a tool lending itself to such a variety of accomplishments as the plain circular saw of trade. I have illustrated some of the results to be attained by the mounting of this implement with relation to the result to be attained.

If some one asked you to make a 2 inch cut with a saw one eighth of an inch thick in one operation, you would hesitate and think a bit. Yet all that is necessary is to set the saw 1 inch off the right angle to its driving shaft. It then becomes a twaddling disk and the width of its cut or groove depends on the angle, which in this case is represented by 1 inch off the true. (See Fig. 7.) If one asked you to bore or saw a round hole, or a square hole, with a circular saw you would doubtless think again; yet as a matter of fact, were a circular saw properly rigged on its shaft, it would form an implement to drill the holes lengthwise through logs for water pipes such as were used in olden times, and are still frequently unearthed on Manhattan Island. To saw a round hole make two cuts at right angles while the saw is set 45 degrees to its axis of revolution. To saw a square hole make one cut with saw at 90 degrees to its axis, while it or the material is moved back and forth a distance equal to its diameter. There is probably no other implement capable, without gears, of boring a hole the axis of the revolution of which is at right angles to the material bored. Should these attainments seem to serve no immediate obvious purpose, they will at least lead us to think, and thought brings to civilization all its artificialities of beauty and utility.

In Fig. 1 the saw is canted to its axis to just the right slant to make a dovetail groove in the edge of a board, which, when fitted to another board with a corresponding tongue, made by two cuts as in Fig. 2, would make locked tongue and groove flooring as in Fig. 4. This process also makes a strong lock jointed wood box. Fig. 6 shows how blocks of material may be locked together, making a cubical base or other structural form. Fig. 7 shows how a thwart cut, or a longitudinal groove, of varying degrees of width may be accomplished. For the first purposes mentioned the placing of the shaft of the saw *S* is below the bed plate as in Fig. 3; for the latter purposes the adjustment is in line or nearly so with the bed plate as in Fig. 8. For architectural ornamentation and similar uses the operation can be accelerated by mounting the cutting-edged twaddling disks like gang saws as shown in Fig. 9. The illustrations are suggestive and may be variously modified. The greater the diameter of saw the less the radius of its curves, and these may be eliminated by up and down motion imparted to the material wrought.

Fig. 4.

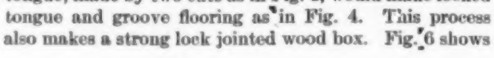


Fig. 5.

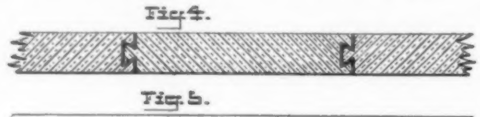


Fig. 6.

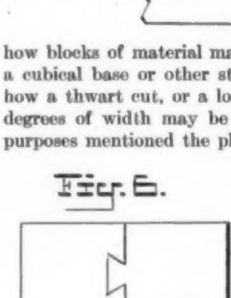


Fig. 7.

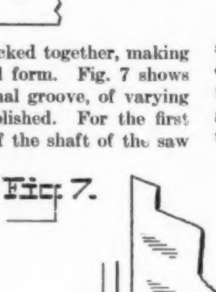


Fig. 8.

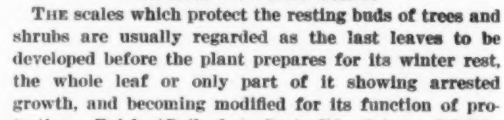
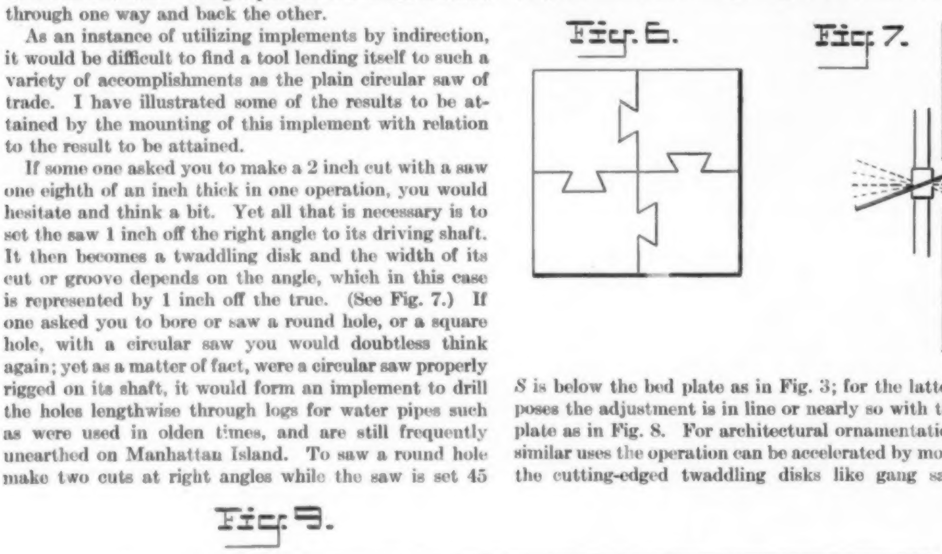


Fig. 9.



It will be observed the work may be varied within large limits, but it must not be expected that an eighth of an inch saw will make a 3 inch cut in the same time it will a full eighth of an inch cut. The feed must adjust to the time for the cut as with all saw operations.

Mount Lasson

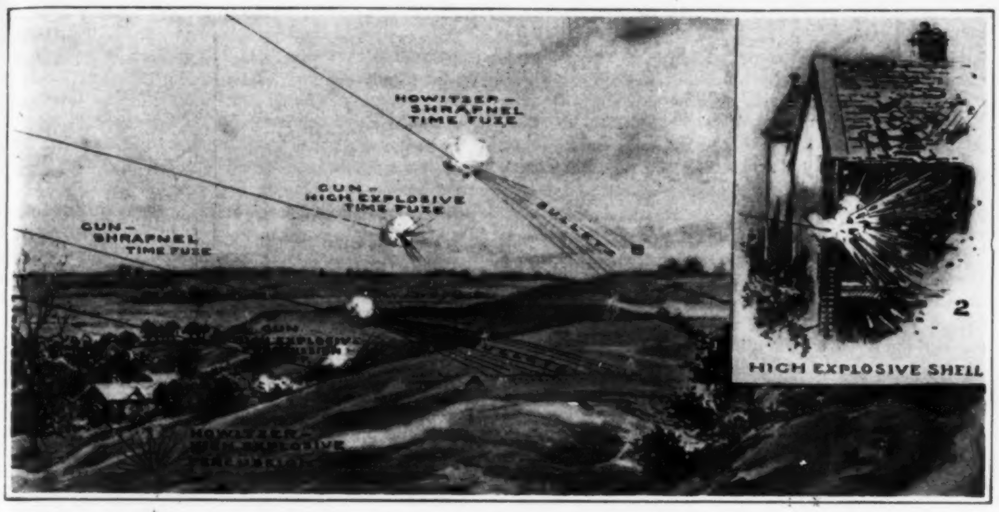
Mount Lassen is regarded as exceptionally interesting from a scientific viewpoint, according to the geological survey, inasmuch as it is the only active volcano in the United States proper, is very accessible to observers, and appears to be full of dangerous possibilities. There is much that is not known about volcanoes, and Lassen is expected by geologists to furnish a considerable addition to existing information on the subject.

It is not known whether a cloudburst started the last eruption by precipitating rain down upon the molten lava in the crater, or whether melting of the snow on the peak, with consequent flowing of water into the crater, caused the accumulation of steam which blew a river of mud out of the mountain. Mr. Diller, who made a study of the volcano last year, said that he inclined toward the melted snow theory, adding that the bright glow reported as appearing on the clouds of smoke and steam over the crater is a reflection of the red-hot matter uncovered by the eruption, indicating that the volcano is in a more or less dangerous mood.

Observations are being made by forest rangers at the scene, and from a fire lookout tower on Brokeoff Mountain, a few miles north of the crater, where the forest service last year kept watch on the numerous eruptions which occurred from May to September.—*Forest Service, United States Department of Agriculture.*

Structure of Bud-Scales

The scales which protect the resting buds of trees and shrubs are usually regarded as the last leaves to be developed before the plant prepares for its winter rest, the whole leaf or only part of it showing arrested growth, and becoming modified for its function of protection. Brick (*Beih. bot. Centralbl.*, Volume XXXI) has investigated the microscopic structure of the bud-scales in a number of plants, comparing their anatomy and development with that of the ordinary leaves in each case, and has added various details to previous knowledge of bud-scale structure. He finds that bud-scales resemble leaves closely in origin and growth, but he draws a sharp distinction between the inner scales and the outermost (oldest) ones. The inner scales resemble leaves arrested in their development, agreeing with ordinary leaves in microchemical reactions as well as structure of the epidermis and mesophyll cells and in the development of air-spaces. The outermost scales, however, have developed on divergent lines, starting at a very early stage, and fall into three distinct groups, for the scale may originate from the rudiment of either: (1) A whole leaf, (2) the basal part only of a leaf, or (3) a leaf in which stipules are already developing. The arrangement of the corky tissue in the outer scale is described in detail, its distribution being such that the bud is enveloped in a closed sheath of corky cells: these outer scales have usually very reduced vascular tissue, so that the scales receive a scanty supply of water, only sufficient to enable them to develop into a protective structure and serve as a corky envelope around the inner portion of the bud.—*Knowledge.*



Essential difference in action between shrapnel and high-explosive shell when bursting among an enemy.

Here we see at a glance the methods of action of the two classes of projectile. Shrapnel is designed primarily as a "man-killing" projectile against troops exposed in the open. "H.E." shell is designed for penetration combined with a locally destructive and all-round shattering effect, as against troops in or behind more or less substantial cover.

Effects of Shell-Fire

How the Various Kinds of Projectiles Work

The projectiles most commonly used by artillery in the field take the form either of shrapnel or high-explosive shell. The former consists of a casing filled with a large number of bullets, and supplied with a bursting charge in its base which serves to drive the bullets forward when the shell bursts and scatter them over a large area. The high-explosive shell contains no bullets, but is entirely filled with the bursting charge, which in its case takes the form of an exceptionally violent explosive, producing instantly a very large volume of gas, and consequently exerting an internal pressure which splits the walls of the shell into fragments and projects them with great force in all directions.

Shrapnel is used with maximum effect against troops in the open, and high-explosive shell against substantial fortifications of all kinds. Shrapnel shell, discharged from a field-gun and exploded in the air above the target by a time-fuse, gives the best results against a body of men unable to take cover. The low trajectory and high velocity of the shell in the case of shrapnel scatters the bullets with which the shell is filled over a long stretch of ground in the direction of its flight (Fig. 1; *A*). Some portion of the charge is consequently pretty certain to hit the object, even though the range may not be quite accurate.

When the enemy's troops are sheltered behind good defenses, or even behind gun-shields, the howitzer must take the place of the field-gun (Fig. 1; *B*). This class of weapon is designed to deliver a "plunging" fire, the shell being thrown upward at a high angle in order that it may fall more or less vertically on the target.

The protection afforded by carefully designed trenches with head-cover is sufficient to enable the occupants to disregard shrapnel bursting in the air above them, because the weight and velocity of the shrapnel bullet is not sufficient to penetrate, or even materially to damage, their shelter. Shrapnel designed to burst on impact is more effective in such a case, but even this form of attack can be successfully resisted with comparatively light defenses. When, however, high-explosive shell is used with the intention of its bursting in the same manner, the most substantial defenses are sooner or later destroyed. A high-explosive shell, striking the wall of a building, explodes on impact, but the velocity of the shell is such that it penetrates the wall during the fraction of a second between the ignition of the fuse and the main explosion, and the effect is produced inside the building, as shown in Fig. 2.

One interesting type of projectile designed for use against air-ships and balloons takes the form of a shrapnel shell having a high-explosive head. In this case the bursting charge in the base of the shell projects the bullets forward after the manner of ordinary shrapnel, and together with them the head of the shell itself. This head is filled with a high-explosive bursting charge, and fitted with a time-fuse. It behaves exactly in the same way as a small, independent, high-explosive shell.

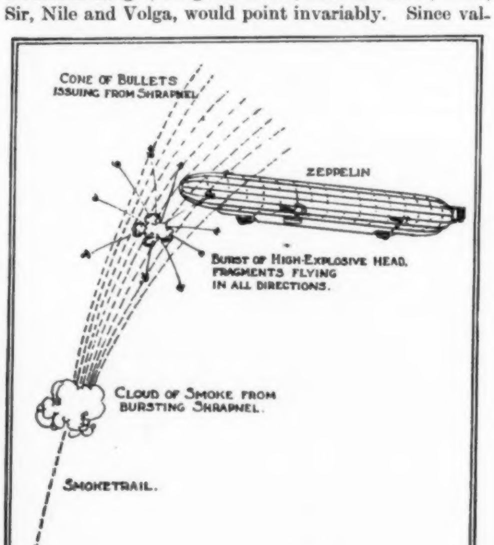
The violent and rapid action of a high-explosive substance when used as a bursting charge in a shell gives the result desired, but these very properties prevent its use as a propelling agent in the gun. The combustion is so rapid—being instantaneous—that an enormous pressure is exerted in the chamber, tending to burst the gun; while the driving effect on the projectile is inferior to that given by a slower burning substance which starts the shell comparatively slowly, but continues to exert pressure on it all the time it is in the barrel until it leaves the muzzle of the gun.—*The Illustrated War News.*

Science and the War

By Dr. Alfred Gradenwitz.

No war has given rise to so rich and variegated a literature as the present struggle of nations which, even long before its outbreak, was much discussed and commented on. Apart from its political side, the economical factors underlying this war have been dealt with time after time. German scientists, however, have gone to the length of considering the world war as a biological phenomenon. Some of the ideas suggested in this connection are resumed in the following:

Prof. A. H. France is of the opinion that in this war "the fatality of the geological structure of the Old World once more asserts itself." (*Voss Gazette*, No. 271.) That part of our globe, in fact, is a colossus whose articulations all converge toward South-eastern Europe. Every people desirous of emigrating with its warriors or merchants thus was unavoidably led to Europe; toward "Arcady" it was that the directions of all large mountain ranges, all giant rivers, such as Indus, Amu, Sir, Nile and Volga, would point invariably. Since valleys are traversed more readily in a downhill than in an uphill direction, the migrations of nations, on account of the special configuration of the Old World, would bring incomparably more people down to the shores of the Mediterranean than in an opposite direction. This biological law is true of animals and plants as well as of men; it even holds in the case of winds and clouds. The following bears out the views of the author:



Generally considered the best projectile against Zeppelins: A high-explosive "Universal" shell bursting, with fragments flying in all directions.

The shell above is described in the last paragraph but one of the article on this page. It combines the action of shrapnel and high-explosive shell. Against a Zeppelin, while the shower of bullets would probably only pepper the gas envelope with comparatively ineffective holes, the detachable head, filled with high explosive, while flying forward amidst the shower of bullets, would burst immediately after impact with the framework of the airship inside the envelope, exploding the gas of the ballonets on either side, and wrecking the airship.

When, in a remote geological past, the sea covered the soil of Germany, a powerful chain of mountains in Russia separated Europe from Asia. These mountains, however, would, at length, tumble down, thus removing any barrier to West-eastern migration. In fact, most of the animals at present peopling Europe have come from Siberia and Central Asia. The trees of European forests, pines and oaks in the first place, may be traced to the same origin, whereas cereals, Alpine flowers, the vine and Southern plants, all are natives of Southern Asia. Europe being open in an easterly direction, while its mountain ranges run from West to East, all atmospheric whirlpools incessantly go from the sea to the interior of the continent, in order there to dissolve. Western meteorological conditions prevail as far as the Russian border, where West-eastern air currents commence, the same that brought Europe the fruits of Asiatic plants.

From the geological structure of the earth it thus follows that, in the center of Europe, there are confined four regions, touching and penetrating into one another and which, according to an ancient natural law, are bound to struggle with each other. Northern Asia aspires westward with particular insistance; Africa and Southern Asia reach there, with their last emanations, across the Balkan bridge and the southern valleys of the Alps. The Atlantic region of animal and vegetable life borders on the West. Now, narrowed in the midst of these three unfriendly neighbors, forming, as it were, a natural "Triple Entente," the central countries of Europe find a free outlet only to the Northward. The eastern region of animal and vegetable life is termed "Pontic Province" by naturalists, the southern region, "Mediterranean," and the western, the "Atlantic" province, whereas Central Europe is known as "Baltic" province, a place upon which elements of Pontic, Mediterranean and Atlantic origin try to make incessant inroads.

The physical structure of Germany and Austria, as above outlined, finds a striking counterpart in the political situation of the two countries. The prehistoric era, as well as the written history of Central Europe, are consequences of this natural situation. The whole of the palaeolithic and neolithic ages were one continuous strife between three races, viz., that of Central Europe, the race coming both from East and West, and the race of African origin, that invaded the Alps. These analogies, which it would be too long to follow up in detail, repeat themselves at the time of the great migrations of nations, and time after time, until the present day. The world war thus can be traced, in the last resort, to geological and biological causes, politics being but a set of physical laws applied to the life of nations.

Another scientist, Prof. von Grubner, a well-known hygienist, in a lecture recently held at Berlin, likewise considers the present war from a biological standpoint. He mainly endeavors to find a philosophical-economical justification of the part played by Germany. "Though we did not desire this war," he said, "we are none the less responsible for it, insofar as war was a biological necessity. By straining our forces to the utmost and by the successes we obtained, we, in fact, incidentally prejudiced other nations. Man, as long as he acts with energy, is bound to become man's enemy. To live means to possess and utilize a surplus of strength. This is how the individual, as well as the nation, becomes a competitor and conqueror. The others, however, incapable as they are to keep pace with the successful rival, are led to unite their efforts, in order to rid themselves of the embarrassing upstart. This tendency is enhanced by differences of character, which confine the possibilities of mutual understanding between nations within narrow limits." German sobriety and systematic, scientific spirit, according to the author, are apt to be mistaken by others for coldness and hardness. However, the most striking contrast is in the different conception of the idea of liberty. "Whereas practically all other nations have endeavored to develop individualism, the German idea of liberty is rather in the sense of a large socialism, and submission to recognized necessities. This, however, is often misinterpreted as servility.

"The actual root of destructive war is found in the struggle for existence. The only means of effectually avoiding war in future, that is, of insuring eternal peace, would consist, on the part of the fittest elements, in foregoing voluntarily any assertion, any growth of their own personality. This renunciation, the ideal of quietism and neomalthusianism, would be contrary to life. A nation full of vital strength must, at the same time, be a nation prepared for war, during war it is that the feelings of such a nation assert themselves most powerfully."

Electric Welding*

The Various Methods in Use and Latest Improvements

By J. H. Bryan

The art of welding, which may be broadly defined as the joining together of metals into intimate and permanent union, dates back to the early days of history. Until within the last half century, the only practicable method of making a weld was by a process with which we are all familiar, namely, that of heating the pieces to be joined at the point where the union was to be made, then, when they were almost at fusing point, placing them in their proper relation and completing the weld by hammering. The introduction of the electric arc welding process and the kindred ones of incandescent electric welding, and also of the gas welding processes, have, however, very greatly increased the field of possibilities, and we are now able to produce results which it was theretofore impossible to obtain.

Before going further, it might be well to outline some broad definitions of the different processes of welding. These may be first divided into two, the first known as Autogenous welding and the second welding by pressure or hammering. The first of these terms, Autogenous welding, may be defined as the fusing together of two metals without pressure by causing them to melt, then unite as they cool. Welding by the use of the electric arc or by the various processes employing gases, such as the oxy-acetylene or oxy-hydrogen method, come under the heading of Autogenous welding.

The blacksmith's weld is one form in which hammering is used to obtain a union of the pieces to be joined. Incandescent welding is another application of the same principle. In this method, as it is most commonly used, the two parts to be joined are placed in contact with each other and by means of suitable equipment a heavy current is caused to pass from one piece to the other. The value of this current is such that it heats the metals to the fusing point, when the two parts are pressed together and the weld thus completed.

A recent modification of incandescent welding is that known as electro percussive welding. It differs from the better known processes in that it is practically instantaneous, this property enabling us to weld metals having widely differing melting points or metals which are not commonly susceptible of being welded. Although this process is of a very recent origin, it has proved very valuable.

ELECTRIC ARC WELDING.

Referring again to electric arc welding as a commercial process, this may in turn be divided into two general classes:

First, Benardos or carbon electrode process in which the arc is drawn between the metal to be welded and a metal electrode.

Second, Slavianoff or metal electrode process in which the arc is drawn between the metal to be welded and a metal electrode.

These two processes are generally referred to as carbon or graphite electrode and metal electrode welding, respectively.

In addition to these there is the Zerener process, in which the arc is drawn between two carbon electrodes, as in an arc lamp, and the metal to be welded is placed in contact with the arc. This is, however, not considered as a commercial proposition, in this country at least, as its field of application is limited, and the apparatus itself is unwieldy.

CARBON ELECTRODE PROCESS.

In carbon electrode welding, the metal to be welded is made one terminal of a direct current circuit, the other terminal being a carbon electrode. Upon closing the circuit by bringing the carbon electrode into contact with the metal and then withdrawing it to a distance, an arc is drawn between the two terminals. Through the medium of the arc, which is the hottest flame known (having a temperature between 3500 degrees and 4000 degrees Centigrade—6300 degrees to 7200 degrees Fahrenheit) the metal may be either entirely melted away, molded into a different shape or fused to another piece of metal as desired.

In the first attempts to weld by this process the carbon electrode was made the positive side of the circuit and the metal to be welded the negative. Practice, however, shows that it is better to reverse these conditions, for if not, since the flow of current is from positive to negative, particles of carbon will find their way into the welds, thus tending to make them exceedingly hard and consequently difficult to machine. A further very important advantage is gained by making the metal to be welded the positive terminal. It is a well known fact that in a direct current arc the highest energy consumption—about 75 per cent of the total—and therefore the highest temperature, occurs at the positive terminal, and, while no very extended data are available regarding the behavior of arcs having either or both electrodes of metal, there is considerable information regarding carbon arcs and it is fair to assume that, with reference to this particular point, there is not a wide difference between them.

METAL ELECTRODE PROCESS.

The metal electrode process of welding is a somewhat later development and it differs in that a metallic electrode is substituted for the carbon.

The essential requirements for arc welding are:

1st. A suitable source of direct current supply. 2nd. A steadying resistance to be placed in series with the arc, together with means for adjusting same, i. e., suitable control equipment. 3rd. A means of holding the electrode so that it may be properly manipulated by the operator. 4th. Protective covering for the operator. 5th. Suitable filling material. 6th. Miscellaneous material such as flux, fire-clay or carbon blocks for making molds, etc.

Taking up this equipment in order, the direct current supply can be obtained in any one of several different ways. If direct current is available from a shop or commercial circuit, welding can be done directly from this source of supply, but this method has been found to be very wasteful of power and should not be resorted to except where welding is to be done only at very infrequent intervals. An additional disadvantage of the use of the shop circuit as a source lies in the fact that, unless arrangements are made for insulating the work from ground, the shop circuit is grounded, with attendant danger to other employees in the shop, as well as to the welding operators. A much more economical method is that of usi g a motor generator set, the motor being constructed with characteristics suitable for operation from the shop or other circuit, and used to drive a low voltage generator.

As different welds require different strengths of current, it is t once evident that there must be some means of regulating the current supply. This is usually effected by inserting resistance in the welding circuit connecting it in series with the arc. Without this resistance, a condition of practical short circuit would occur at the moment the electrode was touched to the work when striking the arc, and, even after the arc is drawn and normal operation begun, the series resistance is necessary for the purpose of steadying the arc, much as is the case in the ordinary arc lamp.

Suitable electrode holders must be provided both for carbon electrode and for metal electrode welding, the construction of the holder being such that the electrode may be renewed in a minimum of time.

Protective equipment is necessary for the operator on account of the fact that exposure to the rays of the arc causes an irritation and subsequent peeling of the skin if the exposure has been sufficiently long, say, several minutes. The irritation is very similar to sunburn and is uncomfortable, but no serious consequences ensue and at the end of a few days all traces of the burn disappear. The clothing has been found to be ample for the protection of the body. For the eyes and face of the operator a hood or shield is provided, both of these being arranged with windows of thick colored glass, through which the welding is observed. The hands and wrists of the operator should be shielded by gauntleted gloves, which are preferably of leather, although canvas gloves have been found satisfactory. The window of the hood or shield should be provided with several pieces of glass in layers, one or more of ruby glass, and one or more of blue or green, the combination of these colors being much more satisfactory than any one of them used alone. There are a number of special welding glasses on the market at the present time, most of which will prove satisfactory.

FILLING MATERIAL.

When the carbon electrode is used, the filling material is usually of the same metal as that being worked upon and may be used in any convenient form. For instance, when welding steel and iron, filling material may be in the form of rods, clippings from boiler plate, steel clippings, etc. For cast and malleable iron, soft iron rods, punched iron scrap or special cast iron filler may be used.

These filling materials are fed into the welds and fused into place much as solder is applied with a blow-torch.

When metal electrodes are used for welding iron and steel they should be of the best quality of soft iron or steel wire and may range in diameter from 1/8 inch or less up to 1/4 inch. The length most generally used is about 12 inches. Copper, bronzes and brasses with a low percentage of zinc may also be welded by this process, in which case the electrodes should be of the same material as that being welded. Where the zinc content of brasses is high, it volatilizes to such an extent as to make the work porous and brittle.

PROCEDURE.

In making a weld by the carbon electrode process, the work is connected to one terminal of the machine, usually the positive, the electrode holder being connected to the opposite terminal. The resistance of the circuit having been adjusted to what is considered the proper value for the work in hand and the circuit breaker and main switch being closed, the operator assumes his position in front of the piece to be welded, taking the electrode holder in one hand and having flux (if same is used) and filling material within easy reach. He finally closes the window of the hood, touches the carbon electrode to the metal to be welded and instantly withdraws it to a distance of 2 inches or more, thus striking the arc. Experience has indicated that with a long arc there is less opportunity for carbon particles to enter the metal and in this way produce a hard weld; the heating effect is also more regular and more evenly distributed. For these reasons the arc should be as long as possible, about 3 inches to 4 inches being the usual length.

After the arc is drawn it is allowed to play upon the work, being given a rotary motion by the hand to heat a comparatively large area of the surface about the weld so that the consequent cooling will take place more slowly and there will be less danger of cracking the work or of making a hard weld. When the metal flows, the flux (if used) and the filling material should be added a little at a time, the arc, of course, being continued until the metal is thoroughly melted and the weld made. As soon as the metal commences to cool it should be hammered thoroughly in order to prevent sponginess and to give the metal a finer grain. All oxide and other impurities must be kept out of the weld. It is advisable, therefore, to make, if possible, one continuous application of the arc. When, however, more than a single application is necessary, care should be taken to remove all the scale. This may readily be done in most cases by means of a stiff wire brush. Similarly the metal should be cleaned before commencing the weld. To accomplish this, chipping may be resorted to or the piece may be tilted, the arc applied and the impurities allowed to run off by gravity as fast as melted.

The current required for carbon electrode welding varies from a minimum of about 200 amperes to a maximum of around 700 amperes, or even more in very heavy work. In general, however, 300 to 400 amperes has been found to be sufficient for ordinary carbon electrode work.

As is indicated in the foregoing, carbon electrode welding is more or less of a puddling process. A considerable amount of heat is generated and this is, in many cases, objectionable on account of the expansion of the work, in which strains may be set up on subsequent cooling and shrinking. In work where trouble of this nature is liable to be experienced, pre-heating may often be used to advantage. On small work this may be done by the use of the carbon electrode. The arc is drawn just as in welding, but it is moved about over the piece without being held in any one place long enough to cause fusion. With larger pieces, a temporary furnace may be made by laying fire brick together loosely to form an inclosure around the work and over it. Heating may be done in any convenient manner either by the use of oil, gas or coal. When the work has reached a red heat, the cover is removed and the welding done without taking the piece from the furnace. After the welding has been completed, the cover is replaced and the work alowed to cool slowly, either with or without a second application of heat.

METAL ELECTRODE PROCESS.

The metal electrode process, though a considerably later development than the carbon electrode method, has a field of application very distinct in many cases from the other process.

A principal advantage of its use is in work where it is desirable to localize the heat to the greatest extent possible, thus minimizing strains due to expansion and subsequent contraction. An example of this is in the welding of sheet metal or of a broken bridge in the flue sheet of a boiler. Another advantage of this process is that it enables welding to be done in a vertical plane or even from the underside of the piece to be repaired. This class of work is done daily in railroad shops in

*Extracts from *Proceedings* of the Engineers' Club of Philadelphia.

repairs to the side sheets and crown sheets of locomotive fire-boxes.

The method of using the metal electrode differs from that with the carbon electrode in the fact that a much shorter arc, generally 1/8 inch to 1/4 inch in length, is used and also in that the electrode forms the filling material as it melts and flows into the fused portion of the work.

With the metal electrode much lower currents are used than in the carbon electrode process. The maximum value hardly ever exceeds 150 to 175 amperes. For a greater portion of the work a current of about 90 to 130 amperes is found satisfactory, although the amount of current required will vary with the size of the electrode and the class of work being done.

CUTTING BY USE OF CARBON ELECTRODES.

The carbon electrode process is also well adapted for cutting of metals. In cutting the arc is drawn just as in welding and is played along the line to be cut, provision being made for the melted metal to run off. Very rapid work of this sort can be done, especially if heavy currents are used.

This process of cutting is used to advantage in work such as cutting off risers and sink heads from castings in a steel foundry, cutting up scrap, and the like, where rapidity and cheapness are of more importance than absolutely smooth finish and accurate work.

APPLICATIONS.

In spite of the fact that arc welding as a commercial process is of comparatively recent origin, it has been found to have a considerable and ever widening field of applicability. It has shown itself to have a distinct range of usefulness, in which it is unsurpassed either by blacksmith welding or by any of the systems of gas welding.

In the repair work of steam railroad shops arc welding equipment has shown itself to be an exceedingly valuable adjunct.

The following figures, taken from records of actual repairs made in a large railroad shop in the Middle West, give a comparison between the actual cost of welding and that of putting the apparatus back into service by methods previously used, either by replacement or by repair of the old parts. The arc welding costs were based on a power cost of 51 cents per hour for the carbon electrode and 17 cents per hour for the metal electrode, together with cost of labor and overhead charge of 40 per cent.

	Cost of Welding.	Cost by other Methods.
Plugging 51 holes in expansion plate holes 1 inch dia. by 1/2 inch deep...	$2.75	$10.15
Repairing mud ring..................	6.50	34.57
Cutting four 6 inch holes in tender deck sheet 1/2 inch thick..........	1.08	8.35
Welding eccentric strap, broken through neck..................	1.08	41.28
Welding two spokes in driving wheel center..........................	7.98	99.98
Welding cracks in side sheets......	26.15	31.79
Repairing fire-box..................	134.89	869.58
Building up flat spots on locomotive driver..........................	.40	225.00

Numerous other figures could be presented showing similar savings.

With reference to the last item given above, namely, that of building up flat spots on locomotive drivers, the repair in this case is effected by welding at the roundhouse without withdrawing the locomotive from service. The tire is simply built up at the flat spot and filed to shape, using a template. Against this the cost of repair by other methods would include the sending of the locomotive to the shop and having the entire set of drivers turned down, which usually means putting the locomotive out of service for at least a week or ten days, as well as the loss of at least one year's wear on the tires. Taking into consideration the loss of revenue from the idle engine, the cost of the older method might easily be $500 or more.

ELECTRIC RAILWAYS.

Electric railways have found an instrument of great value in electric arc welding. In addition to the use of this process in their shops for repairs to their rolling equipment, they are using arc welding for a wide variety of track work, such as rail bonding, frog and switch repairs, low joints, etc.

A large number of electric railways are at the present time doing welding from the trolley circuit, using resistance in series with the arc to hold the current at the required value. Satisfactory work can be done by this method, but it has two very important disadvantages; one of these being it is extremely wasteful of power, and the other, that the danger to the welding operator is very considerable, on account of the fact that one side of the welding circuit is grounded and the operator is in constant danger of serious or fatal injury from shock.

MARINE REPAIR WORK.

An industry of comparatively recent origin is that of the repair of marine boilers. Practically every large harbor now contains one or more repair barges, which are equipped with an arc welding equipment and a compressor for furnishing air for sand blast and pneumatic tools; and are employed in the repair of the boiler equipment of vessels that may arrive in the harbor in need of such repairs. The barge is brought alongside the vessel while the latter lies at the dock, thus enabling the necessary work to be accomplished without loss of time on the part of the steamer.

GENERAL REPAIR WORK.

There are a number of minor applications of arc welding equipment, among which may be classed general repair work in large shops, work in steel plants, cutting up scrap, etc.

Repairs to be taken care of in these shops consist of broken shafts, worn journals and keyways, broken gear-teeth, worn rolls, etc. The welding equipment may be installed permanently and wiring carried to different sections of the shop where welding is likely to be required, or may be made portable and suitable connections for the motor end of the equipment arranged for, as may be required. Still another method is that of installing the motor generator and wiring permanently, and using a portable welding control panel which is connected to the circuit by plugging in at the point where work is to be done.

In steel mills it occasionally occurs that the tap holes or tuyeres of blast furnaces will become plugged with cinder or cold metal. Without the use of the electric arc this would necessitate, in many cases, the loss of the heat and the closing down of the furnace to allow the chipping out of the slag or metal by hand, which is a very slow and tedious process. By the use of the carbon electrode the obstruction may be cut away so rapidly that in most cases operation of the furnace need not be suspended. Where the obstruction consists mainly of metal, it is only necessary that one terminal be connected to the furnace so that a path of reasonably low conductivity to the obstruction is secured. Where, however, cinder is present in such quantities as to make the obstruction of high resistance, it may be necessary to drive an iron bar through the cinder in order to obtain satisfactory results, the bar being melted away and with it the cinder.

The arc welding process has been found to be very well adapted to certain classes of commercial manufacturing operations, replacing smith welding and showing very great savings.

But it is not to be inferred that arc welding is a manufacturing operation primarily, as such is not the case. Its greatest field of usefulness lies in repair work, as distinguished from incandescent welding, which is not at all suited to anything except repetition work, as in manufacturing quantities of duplicate pieces.

No hard and fast rules can be laid down in regard to equipments, as no two installations will be alike in their requirements, and the matter of selection of apparatus of proper capacity is largely one of judgment and experience. It may be said, however, that in general for miscellaneous repair work around large industrial plants a 300-ampere equipment, which is of sufficient capacity to take care of two operators on metal electrode work, or to do, where necessary, light carbon electrode work, is usually satisfactory. For electric railways for track work, a 200 or 300 ampere outfit will be found to be about the proper size.

INCANDESCENT ELECTRIC WELDING.

We come now to a consideration of the other main branch of electric welding, namely, incandescent welding.

Incandescent or resistance welding, as it is sometimes called, is based upon the well known fact that in an electric circuit the introduction of resistance such as is made by a poor contact or conductor, tends to produce heating. There are two distinct processes of this kind, namely, the Thomson and the LaGrange-Hoho, of which the former is almost exclusively used.

The Thomson process is due to Prof. Elihu Thomson and, as stated in his original application which was granted in 1886, "the invention consists in a novel art or process of and apparatus for forming joints between metal wires, bars and the like by the agency of an electric current."

Present commercial processes of incandescent welding, usually spoken of as spot or butt welding, are based on the original Thomson patent. This method will be referred to again in more detail.

The LaGrange-Hoho process, sometimes spoken of as the "water-pail forge," is not, so far as it is possible to ascertain, in use in this country to-day. "In this process an electrolytic bath is employed made from a solution of carbonate of potash and borax in water. . . . The metals to be welded are fastened to the negative terminals of a direct current circuit of 125 to 150 volts, while to the positive terminal is fixed a comparatively large plate of lead, carbon or other suitable conductor. Upon passing current through the circuit the electrolyte commences to decompose, depositing apparently hydrogen on the metal pieces and so developing a gaseous resistance at the points of contact with the liquid. This resistance causes the metal to heat and finally to become incandescent.

"The disadvantages of this process when compared with the Thomson process are apparent, as in the latter the same work is accomplished in substantially like manner without the use of the bath, which item is at all times a nuisance." (Mr. C. B. Auel, *American Machinist*, 1914.)

Referring again to the Thomson process, the apparatus required consists of a source of alternating current, a transformer arranged with a primary coil of suitable characteristics for connection to the A. C. source, and a secondary coil arranged to give exceedingly large currents at potentials varying from one half to 7 volts. The secondary winding of the transformer, since it must handle very heavy currents, is made massive and usually of only a very few turns. Connections are brought out from the secondary circuit to heavy clamps or jaws, water-cooled in the larger sizes, into which the metals to be welded are inserted and gripped. The adjacent ends of the metals which are to be welded are carefully filed and butted together. "Upon closing the primary circuit, current flows through the metals, heating them rapidly at their point of contact to the fusing temperature. While in this softened condition they are forced together either automatically or by hand, thereby uniting perfectly. The shoulder which accompanies each weld is readily removed by a hand file, although on certain classes of work an automatic hammer and anvil are employed for the purpose."

This process has been steadily developed since its inception in 1886 until it is now utilized in an infinite number of ways including the joining of wires or rods of the same or even of dissimilar metals, the making of chains, tires and cylinders, the bonding and welding of rails, the uniting of pipe, the annealing of armor plate, the welding of high speed steel to machine steel, the manufacture of boilers, car wheels and the like.

The amount of current used for any given weld is regulated either by a rheostat or choke coil under the control of the operator, so that heating may be accomplished slowly or quickly as desired.

The heating commences at the center and progresses outwardly; there is no wasted energy. Further, as no foreign substances are used to produce the heat of fusion, such as coal, coke or gas, as in other processes of welding and as no flux is employed, there is no deleterious action upon the metals from these sources. Moreover, there is no change in the electrical conductivity. Tests as to the tensile strength of the welded material indicate that there is a weakening of the metal either directly at the weld, or more usually at a short distance to one side of it, the reduction being given by various investigators as 20 to 30 per cent.

The two classes of work taken care of by the Thomson process are known usually as "butt" and "spot" welding. "Butt" welding is used for welding wires, rods and bars end to end. This is as distinguished from spot welding where the two metals are joined only in spots thus securing the two pieces, much as is the case with rivets. Spot welding is coming into very extensive use at the present time, taking the place of rivets on thin work.

"An interesting application of the incandescent welding process is that of welding street car rails. For welding rails, about 30,000 amperes at 5 to 7 volts are required for two or three minutes, with a pressure of approximately 4000 pounds per square inch, the greatest pressure being exerted when the fusing temperature is reached. Three welds are made at each joint in a total of fifteen minutes, the area of each being about 3 1/2 square inches."

ELECTRO PERCUSSIVE WELDING.

Probably the most recent commercial development in the field of electric welding is that of electro percussive welding, a modification of spot welding. Although this process is related to that of incandescent welding, it is distinctly different in a number of features. In the first place a source of direct current power is required, while in the Thomson process alternating current is used. Also the weld is practically instantaneous by the electro percussive method, while a distinct interval of time is required to allow the metal to heat where the Thomson process is used. Again, by the electro percussive process dissimilar metals, including those which are not ordinarily susceptible of being welded, can be successfully joined. An example of this is in the welding of aluminium wires or of copper to aluminium, copper to platinum, etc.

The electro percussive process as at present developed is designed to take care of comparatively small sections only, but the application to larger sizes is only a question of the design of suitable apparatus.

Briefly, the electro percussive process of welding depends upon the discharge of a high capacity condenser through the points to be welded, together with a forging effect which is practically simultaneous. The apparatus required consists of a direct current generator, a condenser, usually of the electrolytic type, suitable resisters and inductors, together with a forging machine or welding tool.

The process of welding is as follows. The wires are secured in the wire grips and the ends cut off as short as

possible with a suitable pair of cutters. A switch short-circuiting the condenser is then opened, which charges the condenser to the proper voltage. A catch is then released, which lets the sliding member of the welding tool fall and brings the ends of the two wires into percussive engagement. At the instant of contact the short circuited current of the condenser goes up to such a value that the ends of the wire are melted by the explosive discharge and instantly forged together by the blow of the falling mass. The weld is then complete, and after being removed from the machine will be found to have the strength of the original wire.

The generation of the heat is so localized, so sudden and so intense that there is no time for unequal heat conduction through the shanks of the wire and the ends will be melted and even vaporized whether the melting point is high or low. For this reason metals of different kinds can be welded together independently of their electrical resistance, melting point or heat conductance. Any combination of metals which has ever been tried will weld together, but the joints will not be permanent with such combinations as aluminium and tin or lead and iron.

The generation of heat at point of contact depends upon having an appreciable resistance offered to the current at the wire ends and it is therefore necessary to cut the ends of the wire in such a way that they will make a point contact, preferably at the center, so that the energy of the condenser will vaporize a small section of metal and melt the rapidly approaching surfaces with the intense heat of the arc. To do this the wires are cut with ordinary pliers, which give a chisel edge. The two wires are cut off in such a way that the two chisel edges are at right angles and the point of first contact will be at their intersection at the center.

Electrically the weld is complete in 0.0012 second and although 23 kilowatts are being dissipated between the ends of the wire at a certain instant, the total energy use at the weld is only 0.00000123 KWH. or enough to light an ordinary 50-watt, 16 candle-power lamp for 0.90 second. The cost of this amount of energy at ten cents per kilowatt hour would be twelve millionths of a cent.

The inclusion of an inductance in series with the condenser and the electrodes may at first sight seem peculiar. Its purpose, however, is to prolong the current until the final contact of the metals and prevent the explosive snap due to a condenser discharge with small inductance in circuit. Without this inductance, it has been found that a very high frequency oscillation is obtained, causing an explosive discharge, and due to the nature of the electrolytic condenser, the current is suddenly damped, and as the arc goes out before final contact, the wires will not be hot enough to form a good weld. The inductance, therefore, serves the purpose of lowering the frequency of the discharge and prevents the rise of current at the first instant of contact being so sudden as it would be without this inductance.

When the adjustments of inductance and resistance are properly made, the condenser discharge at the moment of contact sounds like a splash or thud instead of a sharp crack. With a certain amount of experience the operator can guess at the settings and it will not be necessary to make any trials. As to the mass and drop of the falling chuck, it must be sufficient to slightly forge the wire. After the setting is once made for any given work, the machine will make a perfect weld every time and the speed of turning out work will only be limited by the handling of the product.

One of the chief advantages of electro percussive welds lies in the fact that they can be made without any apparent change in the properties of the two metals being welded.

Tempered spring steel welded, reduced to uniform diameter, and tested has shown equal or greater strength at and near the weld without any noticeable change in temper. Metals such as hard drawn copper, silver, aluminium, etc., which soften with heat, can be welded together without causing any local annealing, and these metals and steel when soft can be welded together without detrimental local hardening.

Several possible explanations of the constancy of the mechanical properties before and after welding can be given. First, such sudden heating and cooling may not allow change in molecular structure. Second, with hard steel, the heated metal at the weld is so suddenly cooled by conduction of heat into the two shanks of metal that it is again hardened. Third, with hard copper, silver, aluminium, etc., the heating and sudden cooling would ordinarily soften the metal, but the cold forge of the blow in welding possibly hardens it again. Fourth, the metal subjected to the sudden heat cycle may be hardened or annealed (depending upon the characteristics of the material welded), but the amount of material affected may be too small to be detected. As an example, assume a No. 18 hard drawn aluminium wire to be welded together, 0.00123 watt hour or 1.06 small calories are dissipated at the welds. Assume none of the energy lost in noise, radiant heat or metallic vapor, and one half of the total propagated in a heat wave in each direction along the wire. It can be shown mathematically that an annealing temperature will not be reached more than 0.05 millimeter from the weld. The total amount of metal softened would then be a cylinder or disc 0.1 millimeter long and 1.02 millimeters in diameter. A soft insertion of such proportions could hardly be detected. Actual micrographs show that in a case exactly similar to that under consideration the disc of charged metal is only about 0.01 millimeter instead of 0.1 millimeter thick and physical tests fail to show any weakness or softness at the weld after being reduced to uniform diameter by removing the surplus metal of the burr.

Many of the alloys of most metals are very hard and brittle. As an example, there are alloys near both ends of the copper-aluminium series which are unworkable, and yet electro percussive welds between these two metals are so ductile that they may be worked in a die, forged, or rolled into thin foil. Any alloy formed at the weld must range from 100 per cent copper on one side to 100 per cent aluminium on the other; but possibly the brittle combinations are so thin that the joint as a whole is flexible and ductile. This joint between aluminium and copper is of great importance, as copper lead wires, which solder and connect easily, can be readily attached to aluminium coils. At first it was feared that a diffusion of the two metals in service would finally result in a brittle joint, but tests show that after four years the joints are practically as strong and ductile as when first made.

Another feature of particular interest in this process lies in the fact that the electrical resistance of two wires welded together by this process is not appreciably increased. A test made on a wire composed of 85 alternate pieces of aluminium and copper joined with 84 welds in a total length of 23.5 centimeters showed an increase of 0.56 per cent in resistance in three years. This increase is small and it may have been due to a change in the joints or possibly to an error of observation or to oxidation of the wire. The sample in question was rolled and its malleability indicated no appreciable change.

The electro percussive method of welding has opened up a wide field of application hitherto impossible.

In conclusion, it might be said that this method, although it overlaps some of the older processes of welding, meets entirely different requirements and that it will probably never replace these older methods for heavy sections.

Electric Conductors

Electric cables are used for a great many purposes, such as the transmission of electric power, the conduction of telephonic and telegraphic currents, etc. In some cases a cable carries a great many separate currents, and in some cases only a single current. The use of a cable in the transmission of a single current is in general restricted to the cases where the current is large. This requires a large conductor, which for practical reasons is stranded. It may be either a single group of solid wires, or it may have a more complex structure. A seven-strand cable may be a single conductor made up of seven solid wires, or a single conductor made up of seven groups of wires, or a combination of seven conductors insulated from one another. In the latter case, each of the seven strands may be either solid or itself stranded. When one of the strands of a conductor is composed of more than one wire, each element of the strand is also called a strand. Stranded conductors are very commonly formed of concentric strands, which consist of a central core surrounded by one or more layers of helically laid wires. If used as a completed cable, such a conductor is called a concentric-lay cable. Such a group may be combined with others in the same way in which the wires are combined in the group, thus forming a concentric strand composed of elements each of which is a concentric strand. If a concentric strand so formed is used as a completed cable, it is known as a rope-lay cable.

In the long-distance transmission of power, overhead bare cables of copper or aluminium are extensively used. For underground conduit transmission, cables are heavily insulated and rotected by a covering of lead. The insulation may be rubber, varnished cambric, paper, or special compounds. Single-conductor cables of this kind are frequently used for direct current mains. For single-phase alternating service duplex cables are in considerable use. Flat twin cables are most convenient and cheapest where the cable is not unusually large. For alternating currents, two-conductor and three-conductor concentric cables are in great favor. Cables that are to be buried in the earth or used under water have a jute and asphalt covering over the lead, and over that an armor of steel wires or band steel.

Telephone and telegraph cables consist of many wires, each separately insulated with paper, fiber, or rubber, the whole having a light insulating wrapping and a lead sheath. The size of the wires used is more or less standardized, so the size of the cable is roughly indicated when the number of wires is stated, as, e. g., when one speaks of a 200-conductor cable. In a telephone cable the wires are twisted together in pairs.

There are, of course, many special kinds of electric cables, for which trade names have been adopted according to their construction or uses. This holds true also of smaller electric conductors, to which the term "cable" does not apply. The smaller conductors are usually either single wires, stranded wires, or cords. There is a great range of flexibility and of kind of insulation in the various divisions, such as magnet wire, heater cord, lamp cord, etc. The twisted pair is used with many portable electric devices.—*Circular 37, U. S. Bureau of Standards.*

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